10.3 ACTIVE WARMING AND THERMAL INSULATION IN THE PREOPERATIVE AND INTRAOPERATIVE PHASES FOR THE PREVENTION OF IPH

CHARACTERISTICS OF CLINICAL STUDIES INCLUDED IN THE REVIEW (APPENDIX C)

Six studies were included in this pre and postoperative warming mechanisms review (Bock 1998; Buggy 1994; Sheng 2003; Smith 2007; Wong 2007; Wongprasartsuk 1998). The Sheng (2003) study randomised the patients to four groups, with different interventions given in the preoperative (silver hat and jacket versus none) and intraoperative (reflective blanket versus cloth blanket) phases. However, results were not reported separately for the four groups, so that the comparison, preoperative (reflective hats and jackets) plus intraoperative (reflective blanket) versus usual care could not be accessed. Thus, Sheng (2003) became ineligible for the pre and intraoperative review, leaving five included studies. An additional study (Horn 2002) was included as indirect evidence, and is presented separately: patients were pregnant women undergoing elective Caesarean section under epidural anaesthesia. There were no excluded studies for this review.

Study details

A total of 563 patients were included in five studies. Thirty further patients were included in the indirect study, Horn (2002). One study was conducted in the UK (Wong 2007), one in Ireland (Buggy 1994), one in Germany (Bock 1998), and one in Australia (Wongprasartsuk 1998); Smith (2007) and the indirect study, Horn (2002), were conducted in the US. The Smith study was funded by Smiths Medical ASD Inc (the manufacturers of the warming device).

Most studies were of small size, the total number of patients ranging from 26 (Wongprasartsuk 1998) to 336 (Smith 2007). Three of the studies had 20 or fewer patients in the intervention arm (Bock 1998; Wongprasartsuk 1998; Horn 2002, indirect).

Participants

The age range of participants across studies was 14 (Buggy 1994) to 79 years, with the mean age (where given) ranging from 32 to 46 years. Although the Buggy (1994) study of 68 patients had an age range from 14 years, the mean age was 35, so the inclusion of some children was not considered important. One study was carried out exclusively in women (Horn 2002, indirect).

The ASA grade was stated to be I to II in Buggy (1994). Four studies had patients of ASA grades I to III (Bock 1998; Smith 2007; Wong 2007; Wongprasartsuk 1998). For the indirect study, Horn (2002), the patients were said to be 'healthy'.

A range of procedures was undertaken. Two studies included patients undergoing abdominal surgery (Bock 1998; Wong 2007); one in orthopaedics (Wongprasartsuk 1998); one in

1   orthopaedics and plastic surgery (Buggy 1994) and one in gynaecology, orthopaedics, urology

2   and general surgery (Smith 2007). The surgery grade was classified as 2/3 for Buggy (1994),

3   grade 4 for Bock (1998) and unclear in two studies (Smith 2007; Wong 2007).

4

5   Classification by magnitude of surgery was possible for the following studies:

6   •   Patients in three studies had major surgery (Bock 1998; Wong 2007; Wongprasartsuk

7   1998)

8   •   One study was classified as having intermediate surgery (Horn 2002, indirect)

9   •   One study was mixed major and minor (Buggy 1994)

10   •   One study was unclear (Smith 2007; gynaecological /orthopaedic/ urological/ general

11   surgery scheduled greater than 30 minutes: could be major or intermediate).

12

13   All patients received elective surgery under general anaesthesia, apart from the indirect study

14   Horn (2002), which used regional anaesthesia. Four studies gave premedication:

15   •   One study gave 7.5mg midazolam (Bock 1998 oral route, 10 minutes before arrival in the

16   holding area)

17   •   Smith (2007) gave 1 to 2mg midazolam (no details)

18   •   One study gave 10mg oral temazepam or diazepam (Buggy 1994)

19   •   The indirect study, Horn (2002), gave ranitidine 2 hours before surgery.

20

21   The other studies did not mention premedication, but it is not clear if the studies failed to

22   report this or if it was not given: Wong (2007) did give many details about the anaesthetic

23   drugs used; but Wongprasartsuk (1998) gave few details about the anaesthesia.

24

25   The duration of anaesthesia was between 30 and 60 minutes in one study (Buggy 1994) and

26   more than one hour for the other studies. The duration of surgery was 30 to 60 minutes for

27   one study (Buggy 1994); a mean of 1 hour for one study (Smith 2007); 1 to 3 hours for one

28   (Wongprasartsuk 1998); over 3 hours for two studies (Bock 1998; Wong 2007).

29

30   For the indirect study, Horn (2002), the patients received surgery under epidural anaesthesia.

31   Surgery started approximately 80 minutes after induction of anaesthesia and the duration of

32   surgery was 30 to 60 minutes.

33

34   **Interventions**

35   One study (Buggy 1994) gave the patients reflective blankets, four used forced air warming

36   (Bock 1998; Wongprasartsuk 1998; Smith 2007; Horn 2002) and one placed the patients on

37   heated conductive mattresses (Wong 2007).

38

39   The temperature settings and durations of forced air warming were:

40   •   Warm Touch® 40 to 42°C from 30 minutes pre-induction (Bock 1998);

1   •   Bair Hugger® from at least 30 minutes pre-induction (mean 55 to 58 minutes)
2   (Wongprasartsuk 1998);
3   •   Snuggle Warm® convective warming system (SIMS) 40°C (SD 1) from about 30 minutes
4   preoperatively (mean 42, SD 38 min) (Smith 2007);
5   •   Bair Hugger® 43°C from 15 minutes before insertion of epidural catheter (indirect Horn
6   2002).
7
8   **Comparisons**
9   The following comparisons were reported:
10   •   Thermal insulation versus usual care (Buggy 1994);
11   •   Active warming versus usual care (Wongprasartsuk 1998; Horn 2002, indirect);
12   •   Active warming 1 + Active warming 2 versus Active warming 2 (Bock 1998; Wong 2007);
13   •   Active warming + fluid warming (38 to 39°C) versus usual care + PRN active warming and
14   fluid warming (Smith 2007).
15
16   More specifically, the comparisons were:
17   **A. Thermal insulation versus usual care (pre and intraoperative phases)**
18   •   Reflective blankets versus usual care (surgical drape), from before induction – duration
19   not specified:
20   o   No patients received IV fluids during anaesthesia (Buggy 1994).
21
22   **B. Active warming versus usual care (pre and intraoperative phases)**
23   •   Upper body forced air warming versus usual care (cotton blanket), from 15 minutes before
24   insertion of epidural catheter (Horn 2002, indirect).
25
26   **C. Active warming 1 (pre+intra) + active fluid warming (intra) versus active fluid**
27   **warming (intra)**
28   •   Pre+intra: Upper body forced air warming versus usual care (two cotton blankets), for at
29   least 30 minutes before induction: mean 55 and 58 minutes:
30   o   Intraoperatively, both groups received IV fluids warmed with a warming coil
31   (Wongprasartsuk 1998).
32
33   **D. Active warming 1 (pre+intra) + active warming 2 (intra) versus active warming 2**
34   **(intra)**
35   •   Pre+Intra: Upper body forced air warming versus no intervention from 30 minutes before
36   induction:
37   o   Intraoperatively, both groups received circulating water mattress, blankets and fluid
38   warming (Bock 1998);
39   •   Pre+Intra: warming mattress versus placebo warming mattress (switched off), from 30

minutes before induction:

- o   Intraoperatively, both groups received forced air warming (40°C) and fluid warming;
- o   The intervention group also had mattress warming in recovery (Wong 2007).

E. Active patient warming (pre+intra) plus active fluid warming (intra) versus usual care (pre+intra)

- Forced air warming (pre+intra) plus Hotline fluid warming 1.13 litre (38 to 39°C; intraoperatively) versus usual care (pre+intra):
  - o   Control group had PRN active warming and fluid warming intraoperatively at the discretion of the anaesthetist;
  - o   Both groups had warmed blankets preoperatively according to need (Smith 2007).

The GDG decided to combine the results from comparison types (B), (C) and (D). This assumes that the effects from different types of warming are additive. Smith (2007) was treated separately because it was mainly a comparison of the combination of two types of warming versus usual care.

Outcomes

The studies measured the following outcomes:

Primary outcomes:

Only one study (Smith 2007) reported the number of patients with IPH, but most recorded the core temperature at different times. For this core temperature outcome, the GDG considered an increase of 0.5°C over the control group temperature to be clinically significant for a control group temperature above 36.0°C and a difference of 0.2°C to be clinically significant for control group temperatures below 36.0°C.

Core temperature was measured at various times in different studies.
- In the intraoperative period (Bock 1998; Wongprasartsuk 1998; Smith 2007; Wong 2007; Horn 2002, indirect);
- At the end of surgery (Buggy 1994; Smith 2007; Wongprasartsuk 1998; Horn 2002, indirect);
- In PACU (Smith 2007; Wongprasartsuk 1998).

Shivering was measured in five studies (Buggy 1994; Bock 1998; Smith 2007; Wongprasartsuk 1998; Horn 2002, indirect).

Three studies reported patient centred outcomes:
- Thermal discomfort (Buggy 1994; Smith 2007; Wongprasartsuk 1998);
- Pain (Wongprasartsuk 1998).

1

2 Three studies measured core temperature at the tympanic membrane (Bock 1998;

3 Wongprasartsuk 1998; Horn 2002, indirect); one study (Buggy 1994) used a nasopharyngeal

4 temperature probe; one study measured core temperature at the distal oesophagus or

5 nasopharynx intraoperatively and sublingually otherwise (Smith 2007). In one study (Wong

6 2007), baseline and PACU core temperatures were measured at the tympanic membrane and

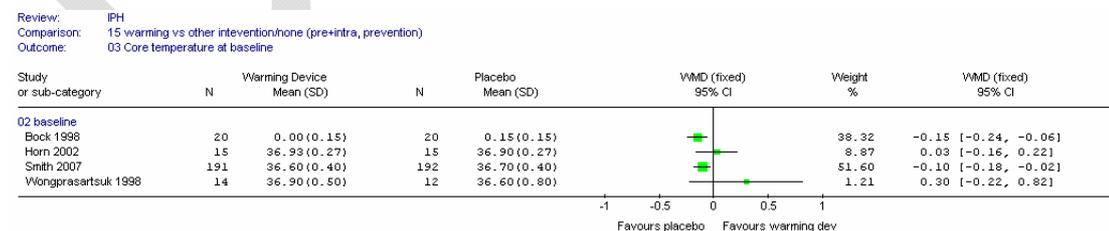7 the nasopharyngeal temperature was recorded in the intraoperative period.

8

9 **METHODOLOGICAL QUALITY OF INCLUDED STUDIES (APPENDIX D)**

10 An adequate method of sequence generation was recorded in three studies (Smith 2007;

11 Wong 2007; Horn 2002, indirect: computer generated), and was not described in the other

12 studies. A partially adequate method of allocation concealment was reported in two studies

13 (Wong 2007: sealed opaque envelopes; and Horn 2002, indirect: sequentially numbered

14 opaque envelopes). The other studies did not report allocation concealment.

15

16 Blinding of the outcome assessors for shivering was stated in three studies (Buggy 1994;

17 Bock 1998; Smith 2007) and not stated in the other study (Horn 2002, indirect). In one study, a

18 blinded observer assessed criteria for discharge from PACU (Bock 1998). Blinding of the

19 outcome assessor for patients' surgical wounds was carried out in one study (Wong 2007).

20 Temperature measurement was not blinded, except postoperatively in one study (Smith

21 2007).

22

23 Baseline comparability was demonstrated in all but one of the studies, at least for age, gender,

24 and duration of surgery. Smith (2007) reported a significant difference in the type of surgery,

25 with more patients having general surgery in active warming group; otherwise this study had

26 no baseline differences. The core temperatures at baseline were examined for both groups in

27 each study, where given, and are plotted below:

28

29 **Figure 1: Core temperatures at baseline**

Review:	IPH							
Comparison:	15 warming vs intevention/none (pre+intra, prevention)							
Outcome:	03 Core temperature at baseline							

Study or sub-category	N	Warming Device Mean (SD)	N	Placebo Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
02 baseline							
Bock 1998	20	0.00(0.15)	20	0.15(0.15)		38.32	-0.15 [-0.24, -0.06]
Horn 2002	15	36.93(0.27)	15	36.90(0.27)		8.87	0.03 [-0.16, 0.22]
Smith 2007	191	36.60(0.40)	192	36.70(0.40)		51.60	-0.10 [-0.18, -0.02]
Wongprasartsuk 1998	14	36.90(0.50)	12	36.60(0.80)		1.21	0.30 [-0.22, 0.82]

-1 -0.5 0 0.5 1
Favours placebo   Favours warming dev

30
31

32 The Wong (2007) study only gave the median and range core temperatures for each group.

33 The median was 36.5°C for each and the authors reported a p-value of 0.880 (i.e. not

34 statistically significant).

35

36 One study (Smith 2007) showed a significant difference in sublingual baseline temperature of

0.1°C. Two studies (Wongprasartsuk 1998: Horn 2002, indirect) showed no significant difference between groups. The Bock (1998) study showed an apparent statistically significant difference in baseline temperatures of 0.15°C, but this is because the time zero for 'baseline' was at induction, i.e. 30 minutes after prewarming for one group. This study only reported change scores from baseline, with their standard deviations, at all other times, and so all values for the prewarmed group are overestimated by 0.15°C. Therefore, we only considered the Bock (1998) study if the effect size was much larger than 0.15°C. In practice, this meant that Bock (1998) was excluded from the analysis for durations up to 2 hours. In a similar way, the baseline difference in Smith (2007) was compared with the effect size.

Three studies carried out a power calculation (Wongprasartsuk 1998; Wong 2007; Horn 2002, indirect). In Wongprasartsuk (1998), in order to detect a difference in postoperative oxygen consumption (VO_2) of at least 20% between the warmed and the control group, the power calculation estimated a sample size of 11 patients for each group. In Wong (2007), in order to detect a 25% reduction in postoperative complications at the 5% level, 80% power calculation estimated a sample size of 50 patients for each arm. In Horn (2002), in order to detect a treatment effect of 1.0°C at the 5% level, 80% power calculation estimated a sample size of 30 for each group.

One control group patient in the Bock (1998) study was transferred to ICU and was not included in the postoperative analyses. In one study (Wongprasartsuk 1998) 4/26 (15%) patients withdrew from the study during baseline measurements complaining of claustrophobia. Forced air warming was ceased in three patients because the core temperature increased above 38.0°C, but data for these patients were included in the postoperative analyses. In one study (Smith 2007), 35/191 (18%) active warming; 12/192 (6%) routine care was excluded from the analysis, mainly for reasons unconnected to the interventions. For the other studies, all patients were included.

Smith (2007) was considered to be partially confounded because 29% of patients assigned to the routine care arm received forced air warming and 9% received warmed fluids at the discretion of the anaesthetist. Although the study also reported results for subgroups of the routine care group that did and did not receive additional warming, the GDG considered these subgroups to be unrepresentative, as they were likely to bias the distribution of lower risk patients. Consequently the GDG decided to use the full (intention to treat) results, which were likely to underestimate the size of the effect.

As mentioned above, three of the studies had 20 or fewer patients in the intervention arm (Bock 1998; Wongprasartsuk 1998; Horn 2002, indirect), although two studies (Wongprasartsuk 1998; Horn 2002, indirect) carried out a power calculation.

1 Bock (1998) was considered to be confounded at early times, and Smith (2007) had a
2 difference in baseline and was partially confounded, but otherwise no studies were thought to
3 have potential for bias.
4
5 **RESULTS**
6 We stratified the studies by type of warming mechanism into active warming and thermal
7 insulation, and treated separately the regional anaesthesia study (indirect Horn 2002).
8 Subgroup analyses were carried out by type of warming mechanism.
9
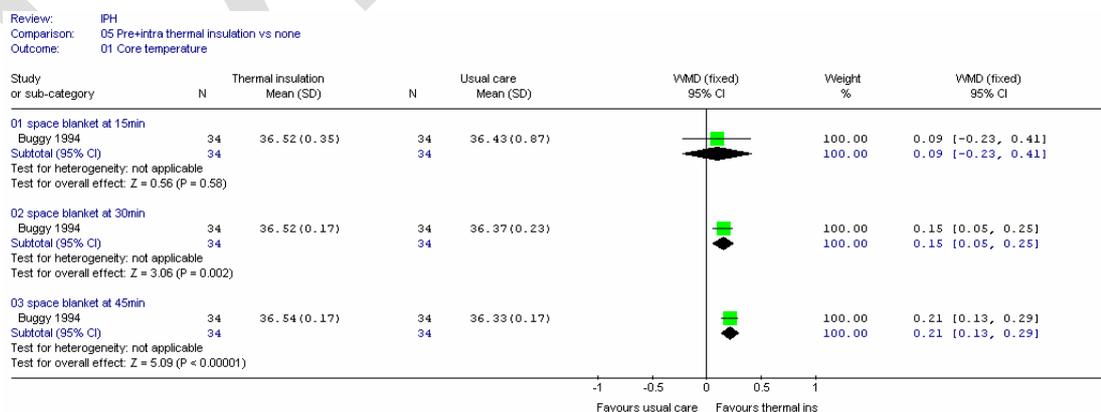10 **I. General anaesthesia**
11 **A. Thermal insulation versus usual care**
12 **1. Core temperature at different intraoperative times (time after induction of**
13 **anaesthesia)**
14 Buggy (1994) studied the effect of a reflective blanket in 68 patients, and recorded the
15 intraoperative temperature at 15, 30 and 45 minutes (Figure 2). The study also reported that
16 there was no difference in initial temperature between the groups (this is assumed to mean
17 at the start of the intraoperative period), despite thermal insulation in one group
18 preoperatively.
19
20 At 15 minutes the difference in core temperature was not statistically significant. At 30
21 minutes the thermal insulation patients had a significantly higher temperature than the
22 control group. MD 0.15°C (95% CI 0.05, 0.25) for a control group temperature of 36.4°C; this
23 is not a clinically important difference. At 45 minutes, the core temperature was significantly
24 higher for the thermal insulation group; MD 0.21°C (95% CI 0.13, 0.29), for a control group
25 temperature of 36.3°C; this difference was not clinically significant.
26
27 **Figure 2: Intraoperative core temperature (15 min, 30 min and 45 min); thermal**
28 **insulation versus usual care**

Review: iPH
Comparison: 05 Pre+intra thermal insulation vs none
Outcome: 01 Core temperature

Study or sub-category	N	Thermal insulation Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 space blanket at 15min							
Buggy 1994	34	36.52(0.35)	34	36.43(0.87)		100.00	0.09 [-0.23, 0.41]
Subtotal (95% CI)	34		34			100.00	0.09 [-0.23, 0.41]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 0.56 (P = 0.58)							
02 space blanket at 30min							
Buggy 1994	34	36.52(0.17)	34	36.37(0.23)		100.00	0.15 [0.05, 0.25]
Subtotal (95% CI)	34		34			100.00	0.15 [0.05, 0.25]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 3.06 (P = 0.002)							
03 space blanket at 45min							
Buggy 1994	34	36.54(0.17)	34	36.33(0.17)		100.00	0.21 [0.13, 0.29]
Subtotal (95% CI)	34		34			100.00	0.21 [0.13, 0.29]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 5.09 (P < 0.00001)							

-1 -0.5 0 0.5 1
Favours usual care   Favours thermal ins

29
30
31 **2. Core Temperature – lowest Intraoperative temperature**

1 The lowest intraoperative temperature was reached at 15 minutes for the treatment group
2 and at 45 minutes for the control group. The result was statistically significant but not
3 clinically significant, MD 0.19°C (0.06, 0.32), for a control group temperature of 36.3°C.
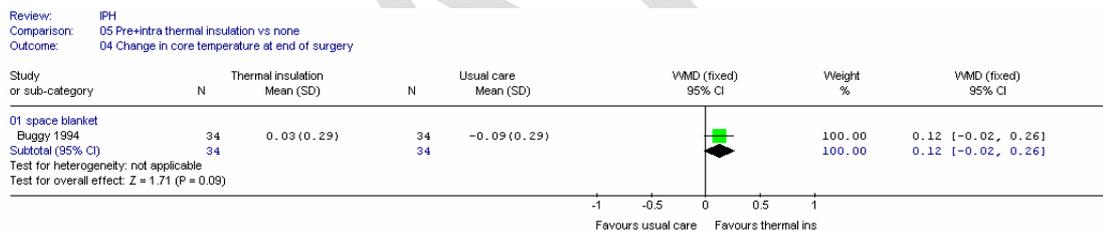4
5 **Figure 3: Lowest intraoperative core temperature; thermal insulation versus usual**
6 **care**


```
Review:        IPH
Comparison:    05 Pre+intra thermal insulation vs none
Outcome:       02 Core temperature lowest temperature

Study                   Thermal insulation        Usual care          WMD (fixed)      Weight      WMD (fixed)
or sub-category     N     Mean (SD)         N     Mean (SD)             95% CI            %          95% CI

01 space blanket
  Buggy 1994        34    36.52(0.35)       34    36.33(0.17)                           100.00    0.19 [0.06, 0.32]
Subtotal (95% CI)   34                      34                                          100.00    0.19 [0.06, 0.32]
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.85 (P = 0.004)

                   -1    -0.5    0    0.5    1
                  Favours usual care   Favours thermal ins
```

7
8
9

10 **3. Change in core temperature at the end of surgery**
11 The mean difference in the temperature at the end of surgery (30 to 60 minutes) was not
12 statistically significant (Figure 4).
13
14 **Figure 4: Change in core temperature at the end of surgery; thermal insulation versus**
15 **usual care**


```
Review:        IPH
Comparison:    05 Pre+intra thermal insulation vs none
Outcome:       04 Change in core temperature at end of surgery

Study                   Thermal insulation        Usual care          WMD (fixed)      Weight      WMD (fixed)
or sub-category     N     Mean (SD)         N     Mean (SD)             95% CI            %          95% CI

01 space blanket
  Buggy 1994        34    0.03(0.29)        34    -0.09(0.29)                           100.00    0.12 [-0.02, 0.26]
Subtotal (95% CI)   34                      34                                          100.00    0.12 [-0.02, 0.26]
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.71 (P = 0.09)

                   -1    -0.5    0    0.5    1
                  Favours usual care   Favours thermal ins
```

16
17
18
19 **4. Shivering**
20 Buggy (1994) assessed shivering during the recovery period in 68 patients. Occurrence of
21 shivering was defined as 'readily detectable fasciculations and tremor of the jaw, neck, trunk
22 and extremities lasting longer than 20 seconds and was assessed by recovery room nursing
23 staff blind to the treatment. There was significantly less shivering for the thermal insulation
24 group, although the confidence interval was wide. The relative risk was 0.24 (95% CI 0.10,
25 0.56), which indicates a 4 times higher risk of shivering for patients given no warming,
26 compared to a reflective blanket (Figure 5). This is a number needed to treat of 3 (95%CI 2,
27 4) for a control group risk of 21/34 (62%).
28
29
30 **Figure 5: Incidence of shivering; thermal insulation versus usual care**

1

2   NB: Scale 0.01 to 100

3
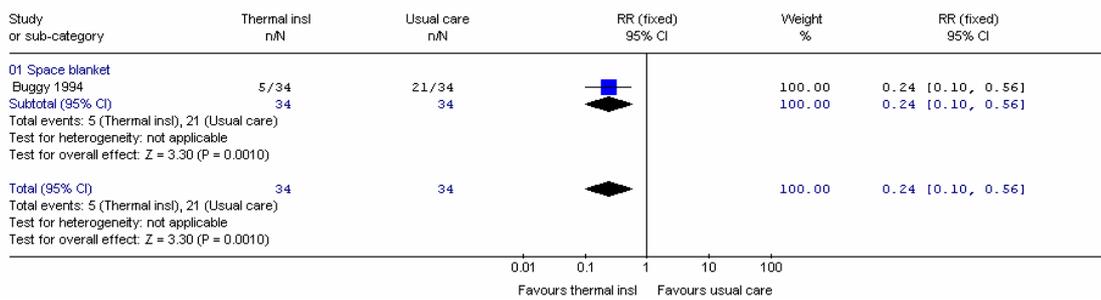
4   **5. Thermal Discomfort (perception of cold)**

5   Buggy (1994) assessed patients' perception of cold at any point since waking in recovery in

6   68 patients. Perception of cold was graded on a linear scale of 1 to 10, with a score of 1

7   indicating *feeling pleasantly warm*, and 10 representing *colder than you've ever felt before*.

8   The mean score was significantly lower for the thermal insulation group, and the effect was

9   large, a difference of -3.30 on a scale of 1 to 10 (Figure 6).

10

11   **Figure 6: Patients' perceptions of cold; thermal insulation versus usual care**

12
13
14
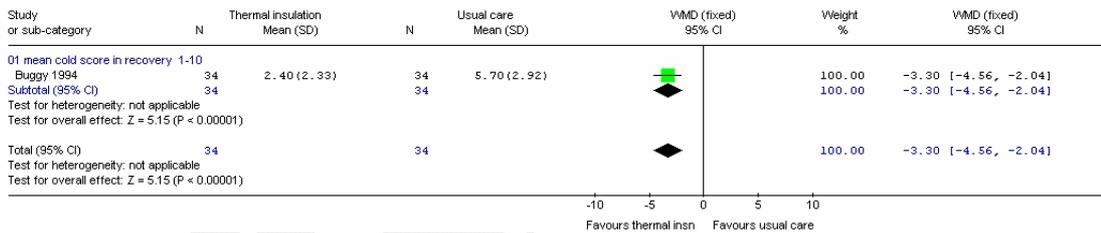
15   **B. Active warming versus usual care**

16   Three studies reported active warming versus usual care (Bock 1998; Wong 2007;

17   Wongprasartsuk 1998).

18   •   Wongprasartsuk (1998) compared in 26 patients, upper body forced-air warming versus

19   usual care in both the pre and intraoperative phases; intraoperatively, both groups

20   received IV fluids warmed with a warming coil.

21   •   Wong (2007) compared in 103 patients, a warming mattress versus placebo warming

22   mattress in the pre and intraoperative phases; both groups had forced air warming and

23   fluid warming in the intraoperative phase.

24   •   Bock (1998) compared in 40 patients, upper body forced air warming blanket used in

25   the pre and intraoperative phases with usual care, and both groups had a circulating

26   water mattress and fluid warming in the intraoperative phase.

27

1   Two direct studies (Bock 1998; Wongprasartsuk 1998) were combined in a meta-analysis,
2   despite differences in duration, site of warming and other intraoperative treatments. The
3   results for Bock (1998) were included in a limited way because of baseline differences. The
4   results for Wong (2007) were not combined because the median and range were given.
5
6   **1. Core temperature at different intraoperative times**
7   Three studies (Bock 1998; Wongprasartsuk 1998; Wong 2007) reported a series of
8   intraoperative temperature measurements and data were extracted from graphs (as
9   appropriate for Bock 1998). The results for Wong (2007) are presented separately as
10 medians.
11
12 **a) 20 minutes (Figure 7)**
13 One study (Wongprasartsuk 1998) in 26 patients reported results on a small graph, for
14 which only the means, ranges and p values were given. It was unclear if the time was from
15 induction or the start of surgery. At 20 minutes, there was no significant difference between
16 groups; MD 0.33°C (p=0.20), for a control group temperature of 36.6°C. The confidence
17 interval was wide.
18
19 **b) 30 minutes (Figure 7)**
20 One study (Wong 2007) reported the intraoperative temperature at 30 minutes (this
21 appeared to be the time into surgery), as median values of 36.2°C and 36.0°C for the
22 warmed (conducting heating mattress + forced air warming + warmed fluids) and control
23 (forced air warming + warmed fluids) groups respectively, but the significance of this
24 difference was not given.
25
26 **c) 40 minutes (Figure 7)**
27 One study (Wongprasartsuk 1998) in 26 patients reported there was no significant
28 difference between groups; MD 0.17°C (p=0.25), for a control group temperature of 36.8°C.
29 The confidence interval was fairly wide.
30
31 **d) 60 minutes (Figure 7)**
32 Three studies reported intraoperative temperatures at 60 minutes (Bock 1998;
33 Wongprasartsuk 1998; Wong 2007). Bock (1998) was excluded from the analysis because
34 of the baseline difference, and Wong (2007) only reported the median values. The
35 remaining study (Wongprasartsuk 1998) in 26 patients reported results on a small graph, for
36 which only the means, ranges and p values were given. At this duration there was a
37 borderline significant difference favouring the warmed group; MD 0.50°C (p=0.053), for a
38 control group temperature of 36.6°C. The confidence interval was wide.
39
40 Wong (2007) reported median core temperatures of 36.2°C and 36.0°C for the warmed

1   (conducting heating mattress + forced air warming + warmed fluids) and control (forced air
2   warming + warmed fluids) groups respectively, but the significance of this difference was not
3   given.
4
5   **e) 2 hours (Figure 7)**
6   Three studies reported the intraoperative temperature at 2 hours into surgery (Bock 1998;
7   Wongprasartsuk 1998; Wong 2007). Bock (1998) was excluded for the reasons stated
8   above and Wong (2007) only reported the median values. The remaining study
9   (Wongprasartsuk 1998) in 26 patients reported there was a statistically significant difference
10   favouring the warmed group; MD 0.75°C (p=0.002), for a control group temperature of
11   36.7°C. The confidence interval was fairly wide.
12
13   Wong (2007) reported median core temperatures of 36.1°C and 36.2°C for the warmed
14   (conducting heating mattress + forced air warming + warmed fluids) and control (forced air
15   warming + warmed fluids) groups respectively, but the significance of this difference was not
16   given.
17
18   **f) 3 hours (Figure 7)**
19   One study reported the change in core temperature 3 hours after induction of anaesthesia
20   (Bock 1998). The temperature difference was statistically and clinically significant, MD
21   0.92°C (95% CI 0.56, 1.28) for a change in control group temperature of -1.65°C. The GDG
22   decided that this difference was sufficiently large compared with the difference in 'baseline'
23   (6 times) so that this outcome could be included.
24
25   **Figure 7: Forced air warming at various times intraoperatively**

Review: IPH
Comparison: 06 Pre+intra active warming device vs usual care
Outcome: 15 forced air warming pre+intra - prevention
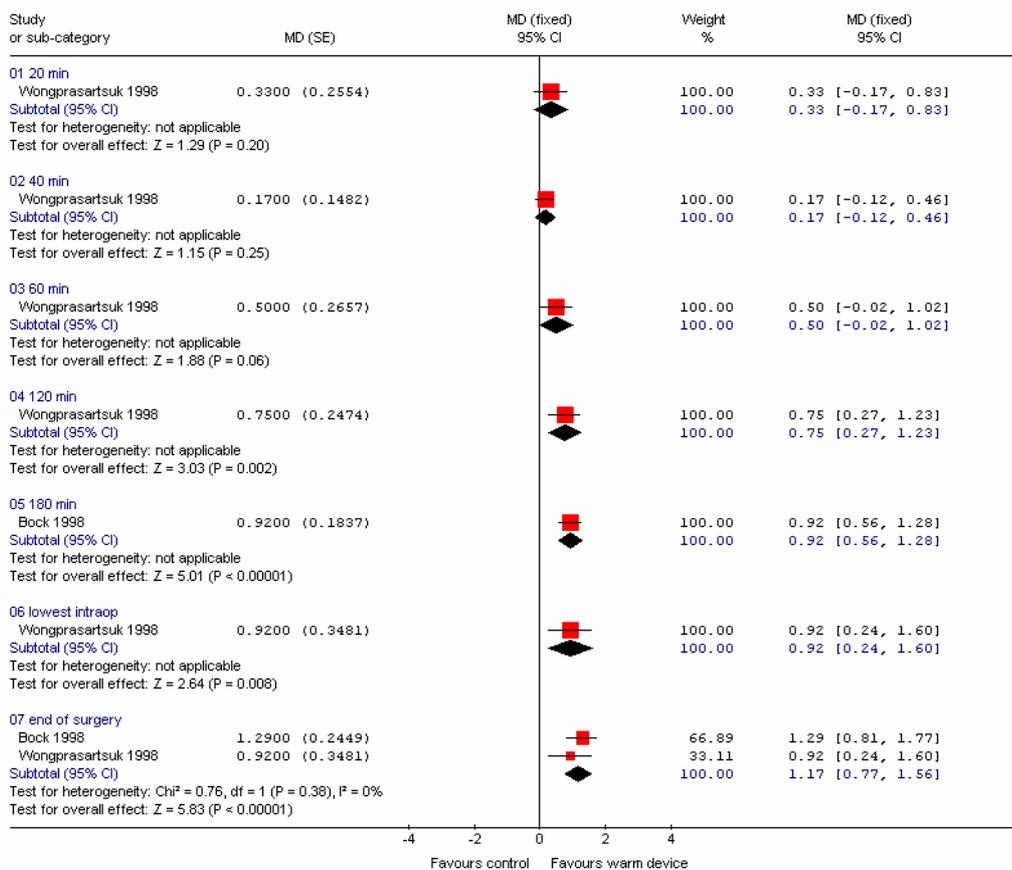
NB: Scale -4 to 4

2. Core Temperature - lowest intraoperative temperature recorded (Figure 8)

In Wongprasartsuk (1998), the lowest intraoperative temperature was recorded at 140 minutes for both groups. As discussed earlier, Bock (1998) was not included in this analysis because of inadequate reporting of the results. The remaining study (Wongprasartsuk 1998) in 26 patients reported there was a statistically significant difference favouring the warmed group; MD 0.92°C (p=0.008), for a control group temperature of 35.9°C. The confidence interval was wide.

In Wong (2007), the lowest median intraoperative temperature was recorded at 30 minutes for the control group (36.0°C) and at 120 minutes for the warmed group (36.1°C).

3. Core Temperature - Final intraoperative temperature (Figure 8)

Three studies (Bock 1998; Wongprasartsuk 1998; Wong 2007) measured the core temperature at the end of the intraoperative period. The duration of anaesthesia was over one hour in all studies. Meta-analysis of the first two studies gave a statistically significant difference, with higher core temperatures for the active warming group: WMD 1.17°C (95%CI 0.77, 1.56), with no heterogeneity (I^2=0%, p=0.38), but the confidence interval was fairly wide.

1
2
3 **4. Core Temperature - PACU**

4 One study (Wongprasartsuk 1998) in 26 patients reported the core temperature upon arrival

5 into the recovery room and at 20 and 40 minutes and at discharge from PACU. The mean

6 difference was clinically and statistically significant on arrival, in favour of the warming

7 group, 0.70°C (95% CI 0.13, 1.27) for a control group temperature of 36.20°C, although the

8 confidence interval was wide.

9

10 **Figure 8: Core temperature - PACU; active warming versus usual care**

11
12 NB: Scale -4 to +4

13
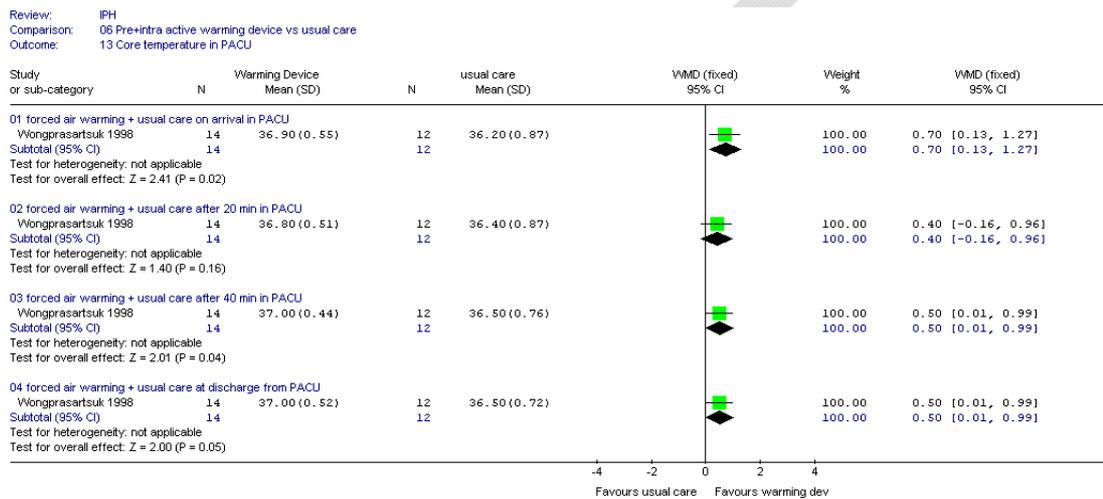
14 **5. Incidence of shivering**

15 Three direct studies assessed shivering during the recovery period (Bock 1998;

16 Wongprasartsuk 1998). Bock (1998) had circulating water mattress plus warmed fluids

17 during the intraoperative period. The studies used different methods to measure shivering:

18 • Wongprasartsuk (1998) assessed the occurrence and duration of shivering. However,

19 the study did not provide details on categories of shivering;

20 • In Bock (1998), the presence or absence of shivering was assessed by an anaesthetist

21 blinded to the groups.

22

23 We dichotomised the categorical outcomes and included all patients with shivering

24 regardless of the severity.

25

26 Meta-analysis of two studies showed a statistically significant reduction in the rate of

27 shivering for the patients receiving forced air warming, but the confidence intervals were

28 very wide. RR: 0.20 (95% CI 0.04, 0.98), which corresponds to an NNT of 6 (5%CI 3, 34).

29
30
31 **Figure 9: Incidence of shivering; active warming versus usual care**

```
Review:         IPH
Comparison:     06 Pre+intra active warming device vs usual care
Outcome:        09 incidence of shivering

Study                    Warming device    Usual care         Peto OR             Weight      Peto OR
or sub-category              n/N              n/N              95% CI                %         95% CI

01 forced air warming vs usual care (60 min preop)
 Wongprasartsuk 1998        1/14             1/12                                  22.53       0.85 [0.05, 14.53]
Subtotal (95% CI)            14               12                                   22.53       0.85 [0.05, 14.53]
Total events: 1 (Warming device), 1 (Usual care)
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.11 (P = 0.91)

03 forced air warming vs usual care; Circulating water mattress and warmed fluids in both groups intraoperativ
 Bock 1998                  1/20             7/20                                  77.47       0.16 [0.03, 0.74]
Subtotal (95% CI)            20               20                                   77.47       0.16 [0.03, 0.74]
Total events: 1 (Warming device), 7 (Usual care)
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.34 (P = 0.02)

Total (95% CI)               34               32                                  100.00       0.23 [0.06, 0.90]
Total events: 2 (Warming device), 8 (Usual care)
Test for heterogeneity: Chi² = 1.03, df = 1 (P = 0.31), I² = 2.6%
Test for overall effect: Z = 2.11 (P = 0.03)

                                                  0.01   0.1      1     10    100
                                              Favours warming dev   Favours usual care
```

NB: Scale 0.01 to 100

Secondary Outcomes in the intraoperative period

6. Blood transfusion

One study (Bock 1998) reported the number of patients receiving 2 units of packed red blood cells during operation. The amount of blood loss and transfusion was estimated by an anaesthetist not involved in the study. There were significantly fewer patients receiving blood, but the confidence interval was very wide.

Figure 10: Blood transfusion – intraoperative period; active warming versus usual care


```
Review:         IPH
Comparison:     06 Pre+intra active warming device vs usual care
Outcome:        14 Blood transfusion

Study                    Warming device    Usual care         Peto OR             Weight      Peto OR
or sub-category              n/N              n/N              95% CI                %         95% CI

03 forced air warming + CWM/fluid warming  vs CWM/fluid (30 min preop)
 Bock 1998                  1/20             6/20                                 100.00       0.18 [0.04, 0.93]
Subtotal (95% CI)            20               20                                  100.00       0.18 [0.04, 0.93]
Total events: 1 (Warming device), 6 (Usual care)
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.05 (P = 0.04)

                                                  0.01   0.1      1     10    100
                                              Favours warming dev   Favours usual care
```

NB: Scale 0.01 to 100

7. Duration of stay in PACU/Discharge from PACU

One study (Bock 1998) reported the time to discharge from PACU. A core temperature of greater than 36°C and a score of 14 points (out of a total of 24 points) on a modified version of Aldrete and Kroulik scoring system (Aldrete and Kroulik 1970) were the criteria for discharge. Criteria for discharge on the Alderete and Kroulik scoring system was assessed retrospectively by a blinded observer. The time to discharge was significantly lower for the prewarmed patients (active + CWM/Fluid group) by 123 minutes, but the confidence interval was fairly wide.

Figure 11: Time to discharge from PACU; active warming versus usual care
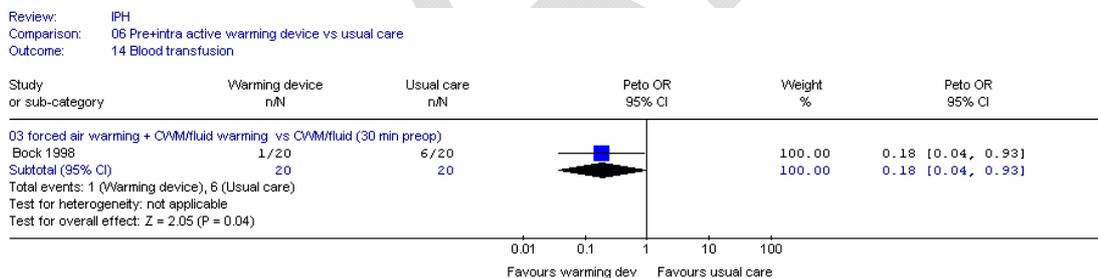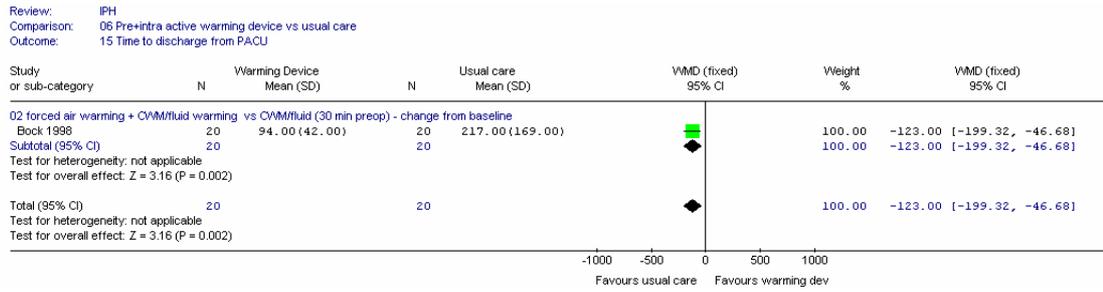
NB: Scale -1000 to +1000

Secondary outcomes in the postoperative period

One study (Bock 1998) reported secondary outcomes in the postoperative period.

8. Blood products (PACU)

One study (Bock 1998) reported the volume of blood products (millilitres/patient) given on admission to PACU. The volume of blood products was significantly less for prewarmed patients by 210 ml/patient.
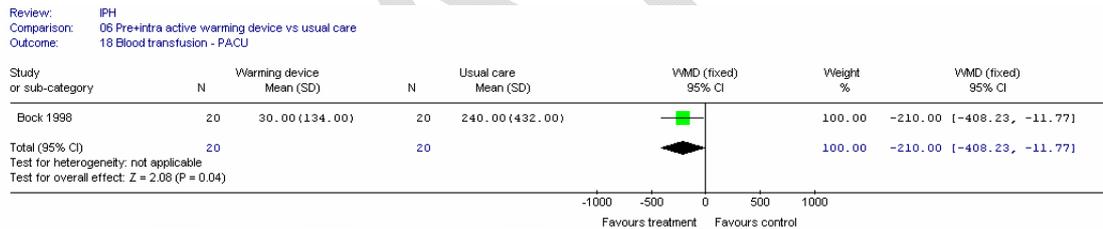
Figure 12: Volume of blood products infused (PACU); active warming versus usual care

NB: Scale -1000 to 1000

9. Adverse effects

One study (Wongprasartsuk 1998), in 26 patients, reported the incidence of hyperthermia (a temperature greater than 38ºC), it was assumed in PACU. 4/14 patients in the intervention group and 0/12 in the control group had overheating adverse effects.
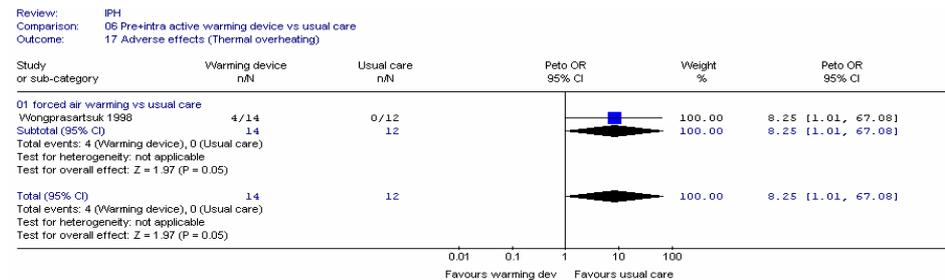
Figure 13: Adverse effects (thermal overheating); active warming versus usual care

NB Scale 0.01 to 100

1

2 **a) Postoperative pain**

3 One study (Wongprasartsuk 1998), in 26 patients, reported postoperative pain 20 and 40

4 minutes after arrival in PACU. Postoperative pain scores were assessed on a visual

5 analogue scale (0-10cm); however, the scale was unclear and there were no standard

6 deviations given. At 20 minutes, the mean pain score for the treatment group was 5.6 and it

7 was 5.5 for the control group (NS; p=0.74). After 40 minutes in PACU, the treatment group's

8 mean pain score was 5.7 and it was 6.1 for the control group.

9

10 **b) Thermal discomfort**

11 One study (Wongprasartsuk 1998) reported postoperative thermal discomfort 20 and 40

12 minutes after arrival into PACU. Postoperative thermal discomfort was assessed on a visual

13 analogue scale (0-10mm), with the scale not described.

14

15 **C. Active warming (pre+intraoperatively) plus active fluid warming (intraoperatively)**

16 **versus usual care**

17 One study (Smith 2007), in 336 patients, compared the combination of forced air warming in

18 both pre and intraoperative phases with actively warmed IV fluids versus routine care. The

19 routine care arm, however, included patients who were warmed at the discretion of the

20 anaesthetist (29% received forced air warming and 9% received warmed fluids). The

21 intervention and control groups respectively received a mean of 1.13 litres (SD 0.4) and

22 1.09 (SD 0.4) of crystalloid over a mean of 56 minutes anaesthesia time.

23

24 **1. Incidence of IPH at the end of surgery**

25 Smith (2007) reported the incidence of IPH at the end of surgery (56 minutes mean) for

26 definitions of less than 36.0°C and less than 35.5°C. There was a large statistically

27 significant difference for both definitions, with less IPH for the intervention group. For the

28 definition, less than 36.0°C, the relative risk was 0.32 (95% CI 0.22, 0.47), for a control

29 group rate of 53%. This corresponds to an NNT of 4 (95% CI 3, 5).

30

31 **Figure 14: Incidence of hypothermia; active warming versus usual care**
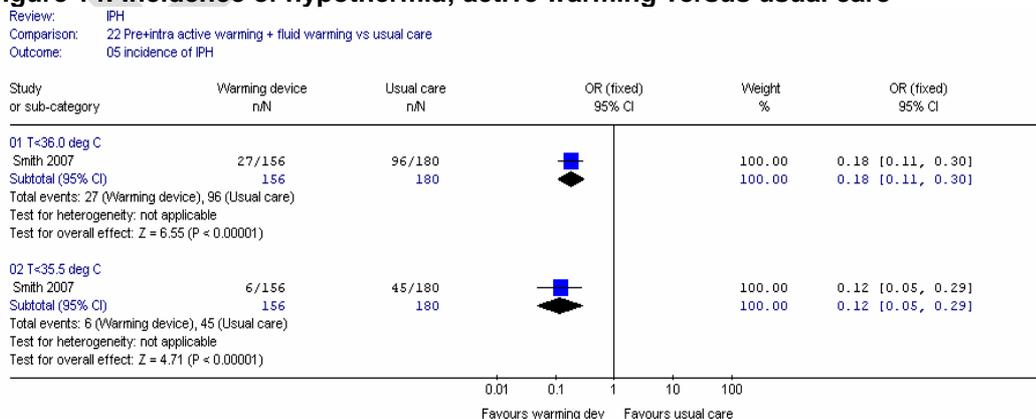

32

1

2 **2. Core Temperature - lowest intraoperative temperature recorded (Figure 15)**

3 In Smith (2007), the lowest intraoperative temperature was recorded at 25 minutes for the

4 warmed group and 35 minutes for the control group. The core temperature was significantly

5 higher for the intervention group; MD 0.90°C (95% CI 0.78, 1.02) for a control group

6 temperature of 35.6°C. We note that this effect size is considerably larger than the

7 difference at baseline (0.1°C).

8

9 **3. Core Temperature - Final intraoperative temperature (Figure 15)**

10 The core temperature was significantly higher for the intervention group at the end of

11 surgery (mean duration 56 minutes; mean duration of anaesthesia 94 minutes); MD 0.60°C

12 (95% CI 0.48, 0.72) for a control group temperature of 35.8°C. This difference is much

13 larger than the baseline difference.

14

15 **Figure 15: Core temperature – lowest and final intraoperative; active warming versus**

16 **usual care**

17

18
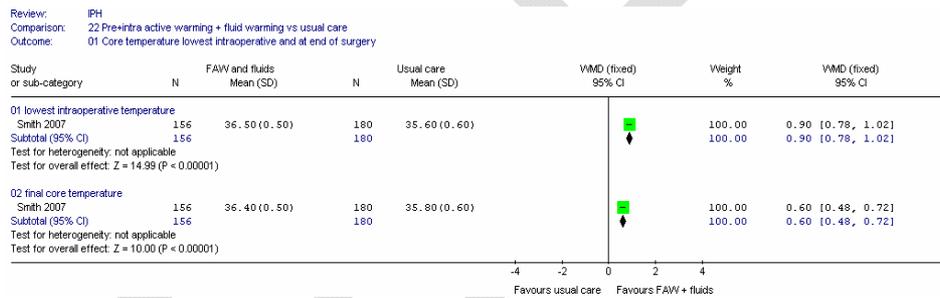
19 **4. Core Temperature – PACU**

20 One study (Smith 2007) in 336 patients reported the sublingual temperature upon arrival

21 into the recovery room and at 30 and 60 minutes. The core temperature was significantly

22 higher for the intervention group on arrival, MD 0.4ºC (95% CI 0.29, 0.51) for a control group

23 temperature of 36.0°C. This was similar after 30 minutes in PACU (MD 0.4ºC [95%CI 0.3,

24 0.5]). At 60 minutes the difference was 0.2ºC (95% CI 0.1, 0.3) and at discharge was 0.2ºC

25 (95% CI 0.11, 0.29).

26

27 **Figure 16: Temperature in PACU; active warming versus usual care**
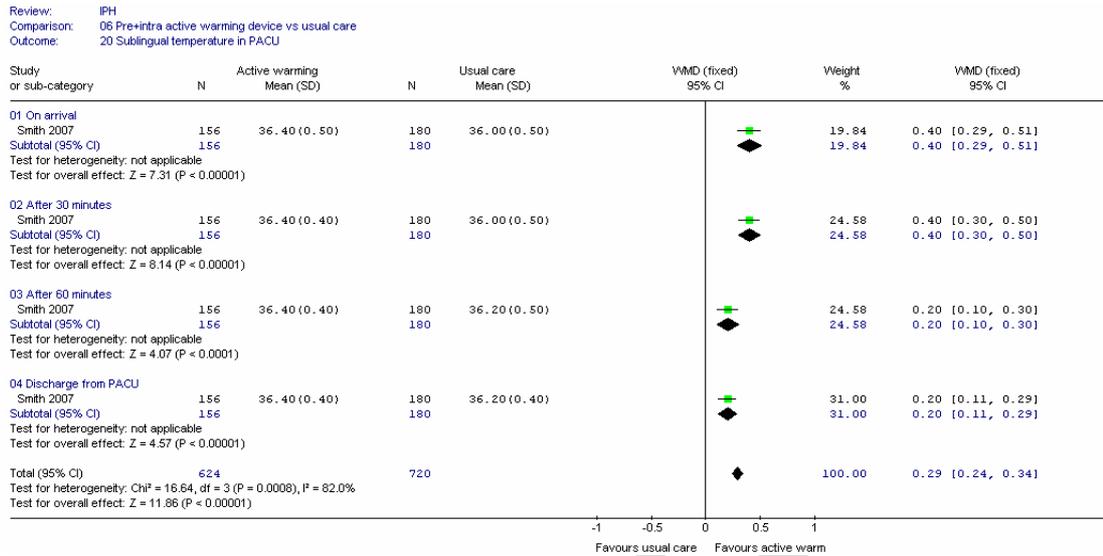
5. Incidence of shivering

Smith (2007) reported shivering in 5/156 actively warmed patients and 36/180 patients treated with usual care. Of these, 4 (2.6%) and 31 (17%) respectively were classified as severe shivering. Significantly fewer patients had shivering in the intervention group compared with the control group, but the confidence interval was wide.

Figure 17: Shivering; active warming versus usual care
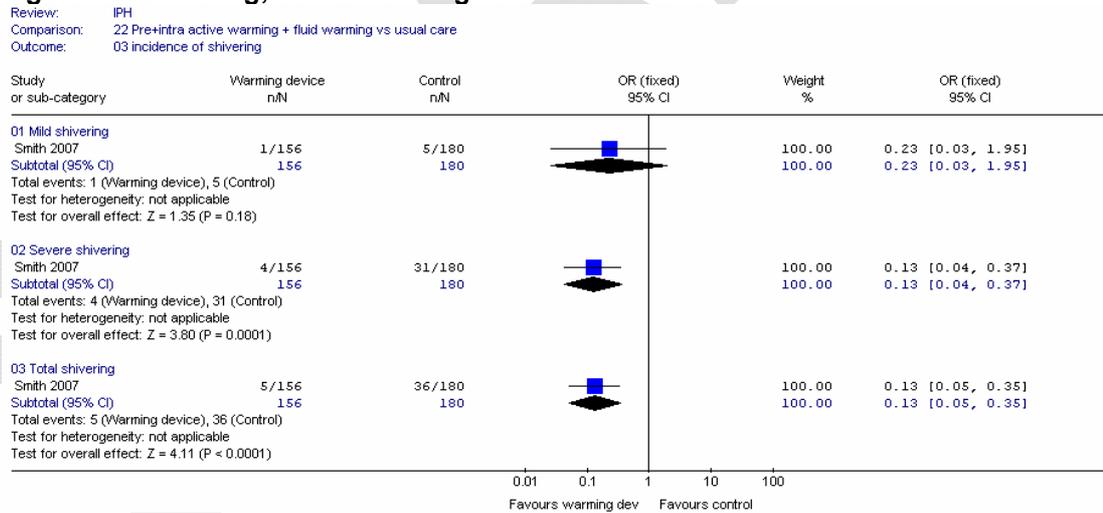
NB Scale 0.01 to 100

Secondary Outcomes

6. Duration of stay in PACU

There was no significant difference in the time to discharge (1 minute).

Figure 18: Duration of stay in PACU (minutes); active warming versus usual care

Review: IPH
Comparison: 06 Pre+intra active warming device vs usual care
Outcome: 22 Duration of stay in PACU

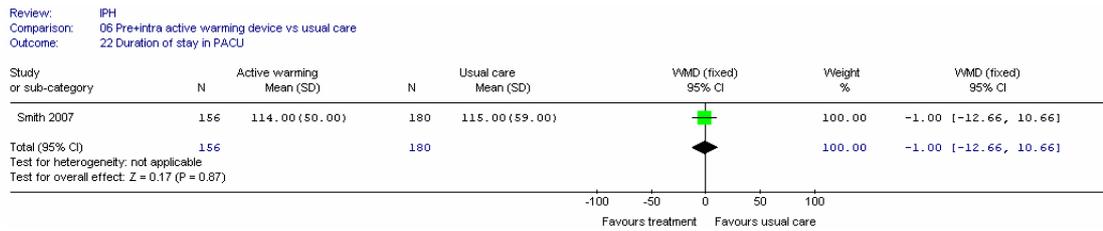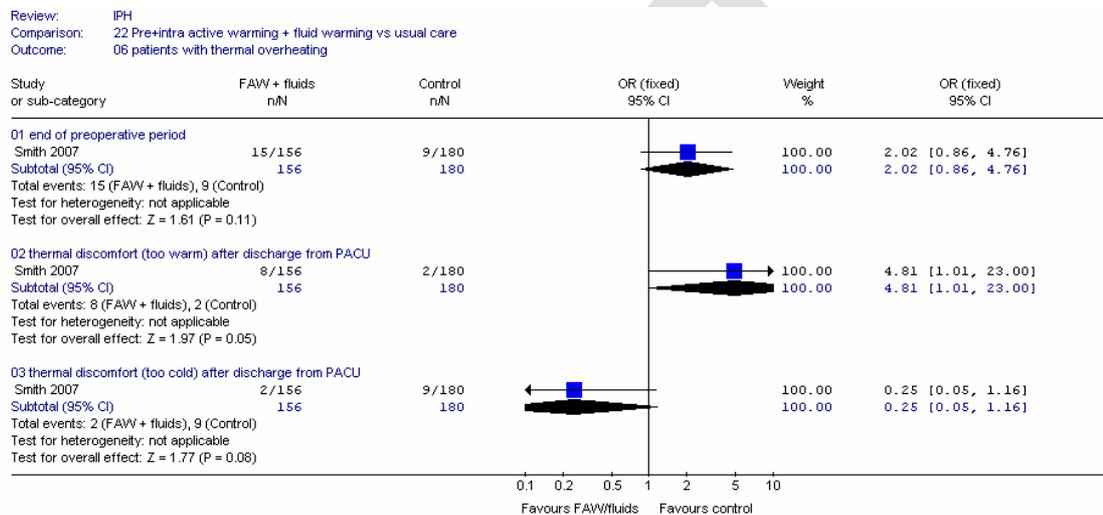| Study or sub-category	N	Active warming Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Smith 2007	156	114.00(50.00)	180	115.00(59.00)		100.00	-1.00 [-12.66, 10.66]
Total (95% CI)	156		180			100.00	-1.00 [-12.66, 10.66]

Test for heterogeneity: not applicable
Test for overall effect: Z = 0.17 (P = 0.87)

-100   -50   0   50   100
Favours treatment   Favours usual care

7. Thermal discomfort

Smith (2007) also reported significantly more patients assessed themselves to be too hot postoperatively, but the confidence interval was wide.

Figure 19: Adverse effects (thermal overheating); active warming versus usual care

Review: IPH
Comparison: 22 Pre+intra active warming + fluid warming vs usual care
Outcome: 06 patients with thermal overheating

Study or sub-category	FAW + fluids n/N	Control n/N	OR (fixed) 95% CI	Weight %	OR (fixed) 95% CI
01 end of preoperative period					
Smith 2007	15/156	9/180		100.00	2.02 [0.86, 4.76]
Subtotal (95% CI)	156	180		100.00	2.02 [0.86, 4.76]

Total events: 15 (FAW + fluids), 9 (Control)
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.61 (P = 0.11)

02 thermal discomfort (too warm) after discharge from PACU					
Smith 2007	8/156	2/180		100.00	4.81 [1.01, 23.00]
Subtotal (95% CI)	156	180		100.00	4.81 [1.01, 23.00]

Total events: 8 (FAW + fluids), 2 (Control)
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.97 (P = 0.05)

03 thermal discomfort (too cold) after discharge from PACU					
Smith 2007	2/156	9/180		100.00	0.25 [0.05, 1.16]
Subtotal (95% CI)	156	180		100.00	0.25 [0.05, 1.16]

Total events: 2 (FAW + fluids), 9 (Control)
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.77 (P = 0.08)

0.1   0.2   0.5   1   2   5   10
Favours FAW/fluids   Favours control

II. Regional Anaesthesia

A. Active warming versus usual care

One indirect study in women undergoing Caesarean section under epidural anaesthesia (Horn 2002) reported a series of intraoperative temperature measurements and data were extracted from graphs. In Horn (2002), the same warming method was employed through the intraoperative period as in the preoperative period.
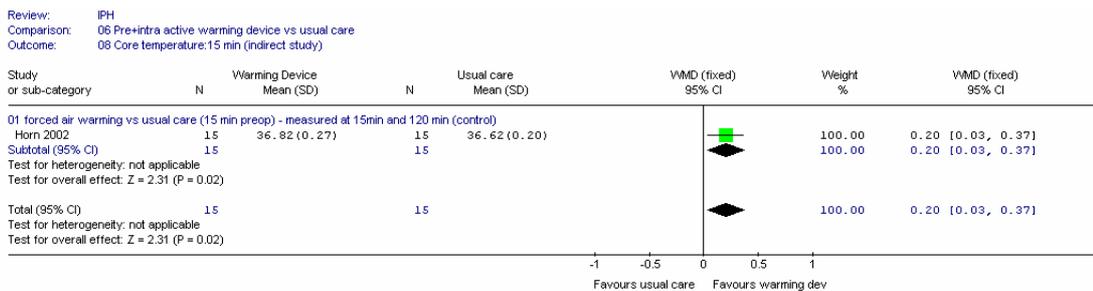
1. Core Temperature at different intraoperative times

a) 15 minutes

Horn (2002) recorded the intraoperative temperature 15 minutes into the surgery. The core temperature was significantly higher for the intervention group; MD 0.20°C (95% CI 0.03, 0.37) for a control group temperature of 36.62°C; this was not clinically significant.

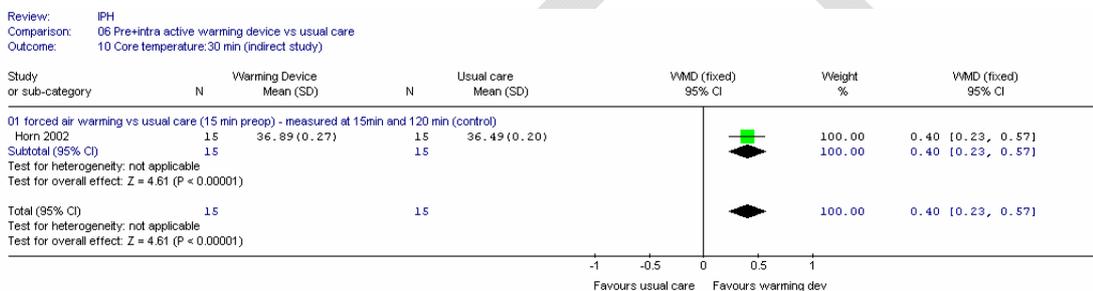**Figure 20: Core Temperature intraoperative temperature at 15 minutes into surgery; active versus usual care**

b) 30 minutes

In the indirect study, there was a significantly higher core temperature for the intervention group, MD 0.40°C (95%CI 0.23, 0.57) (Figure 20)

Figure 21: Core Temperature intraoperative temperature 30 minutes into surgery; active versus usual care


c) 2 hours

In the indirect study, with 30 patients (Horn 2002) there was a significantly higher core temperature for the intervention group, MD 1.21°C (95% CI 0.97,1.45).

2. Lowest core temperature

The lowest intraoperative temperature measurement for the warming group was recorded at 15 minutes after induction. The control group showed a decline in core temperature 60 minutes after induction and reached its lowest point at 120 minutes. The core temperature was significantly higher for the intervention group; MD 0.87°C (95% CI 0.65, 1.09), for a control group temperature of 35.95°C (Figure 22).

Figure 22: Core temperature – lowest intraoperative temperature; active warming versus usual care
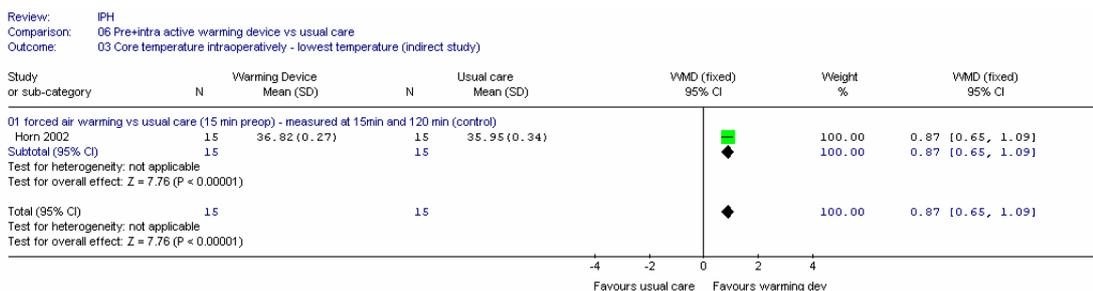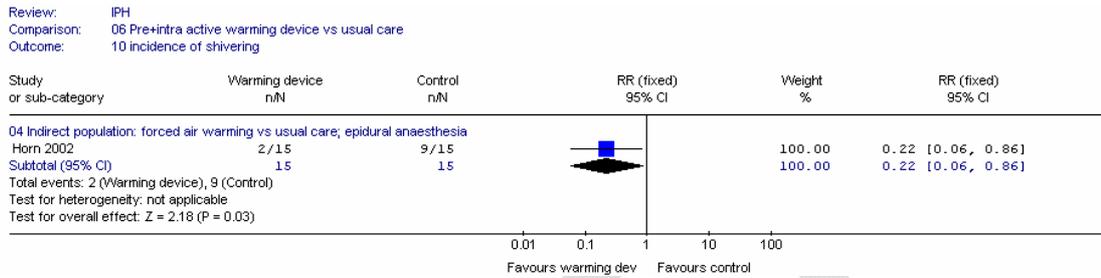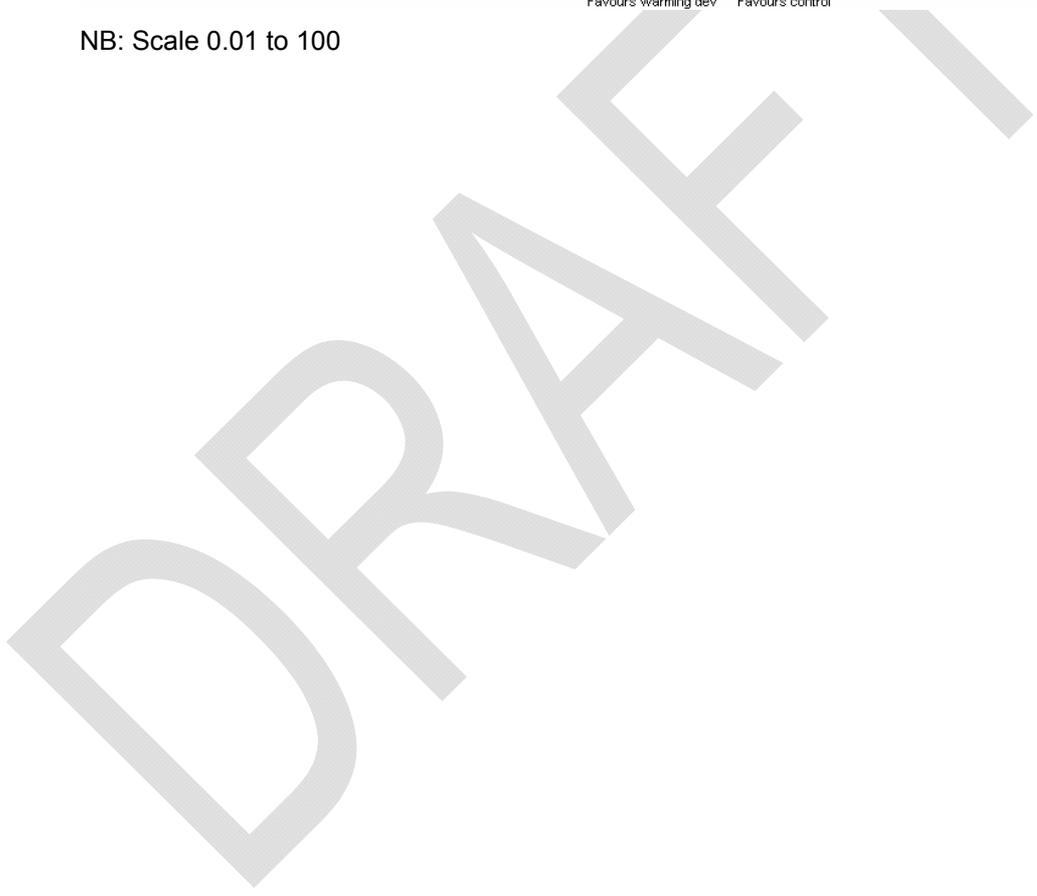
1 **3. Shivering**

2 The indirect study, Horn (2002), also recorded shivering, using a 4 point scale (0=none;

3 1=low; 2=moderate; 3=continuous) by an investigator blinded to core temperatures. There

4 were significantly fewer patients shivering in the intervention group, but the confidence

5 interval was wide.

6

7 **Figure 23: Shivering (indirect study); active warming versus usual care**

Review: IPH
Comparison: 06 Pre+intra active warming device vs usual care
Outcome: 10 incidence of shivering

Study or sub-category	Warming device n/N	Control n/N	RR (fixed) 95% CI	Weight %	RR (fixed) 95% CI
04 Indirect population: forced air warming vs usual care; epidural anaesthesia					
Horn 2002	2/15	9/15		100.00	0.22 [0.06, 0.86]
Subtotal (95% CI)	15	15		100.00	0.22 [0.06, 0.86]
Total events: 2 (Warming device), 9 (Control)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 2.18 (P = 0.03)					

0.01   0.1   1   10   100
Favours warming dev   Favours control

8

9 NB: Scale 0.01 to 100

10

10.4 Adverse effects arising from warming devices used for the prevention or treatment of inadvertent perioperative hypothermia

Introduction

The importance of avoiding perioperative hypothermia is well established. There are several advantages perioperatively including reducing blood loss, wound infection, duration of intensive care and hospital stay. Other great advantages also include reducing the risk of cardiac ischaemia and increasing patients' survival. This will, consequently, create comfort and safety for the patient and reduce health care cost. In order to maintain normal temperatures perioperatively a range of medical warming devices have been developed and are currently used in most of the clinical institutions. However, there are a small number of adverse effects relating to warming devices when used for the prevention or treatment of inadvertent perioperative hypothermia.

Objective

To determine adverse effects arising from warming devices used for the prevention or treatment of inadvertent perioperative hypothermia.

Selection criteria

Selection of studies

We sought all available published studies in which the adverse effects of warming devices had been evaluated. We used reports previously retrieved for the effectiveness reviews (see Appendix B) and ran a new search strategy in MEDLINE and EMBASE for adverse effects. This included a combination of MeSH terms and search words as specified in detail in Appendix B. We also checked the reference lists of relevant studies and review articles. A total of 77 citations were retrieved of which full text of 49 published studies were screened.

Study Design: inclusion and exclusion criteria

We included studies of adults of eighteen years and over undergoing surgery or other procedures under general or regional anaesthesia, published as randomised trials (RCTs) and quasi-randomised studies. Observational studies (1) (prospective and retrospective), mainly cohorts, were also to be included. Case reports and case series were permitted, but we note that these tend to report more unusual experiences, making them more prone to reporting and publication bias (selected interesting cases). Thus, these reports may not be very representative of the general patient population. Studies were restricted to the English language and there were no date restrictions.

We excluded studies in children, patients undergoing surgery under local anaesthesia, patients undergoing therapeutic hypothermia and those with head injuries resulting in impaired

temperature control. Studies in pregnant women and post-bypass patients could only be included as indirect evidence.

Characteristics of studies

From 73 articles identified, we selected 46 potentially relevant studies. After exclusions, a total of 21 studies were included. Characteristics of the studies included in this review are detailed in Appendix C.

The studies were conducted in several countries including the UK (Batistich 2006; Huang 2003; Avidan 1997; Ayala and Coe 1997; Baker 2002; Tumia 2002), the USA (Zuokumor 2004; Frolich 2001; Husser 2004; Kressin 2004; Gali 2003; Zwkowski 1998; Sigg 1999; Cheney 1994; Zink 1993), Canada (Hemmerling 2002), France (Guignard 2000), and China (Ng 2006). Two studies did not report the country where they were conducted (Marders 2002; no authors listed, 1990). The studies were generally small (N ranged from 1 to 60) and 50% of these were case reports.

The following are the types of study included:

- Two observational retrospective insurance studies comprising claims from 28 patients (Cheney 1994) and 64 patients (Kressin 2004)
- Two RCTs, which simply discussed adverse effects, not as a randomised comparison (Ng 2006; Camus 1997)
- Eight case reports (Zuokumor 2004; Guignard 2000; Frolich 2001; Ayala and Coe 1997; Batistich 2006; Husser 2004; Gali 2003; Zukowski 1998)
- Three case series reports: one of 10 patients which included two sets of 5 individuals (Hemmerling 2002) and two reports of two patients each (Marders 2002; no authors listed 1990).
- Five experimental cross infection reports. Two of the reports (Avidan 1997; Sigg 1999) examined bacteria plates from Bair Huggers®. Avidan (1997) examined bacteria plates from 10 patients, with 2 control plates; Sigg (1999) examined bacteria plates from 18 patients, with 10 control plates. Another study (Tumia 2002) examined samples from bacteria tests performed on 4 patients, with control samples obtained from an empty theatre. The fourth study (Baker 2002) collected swab bacteria samples from the interior and the exterior of a forced air warming (FAW) device (WarmAir warming unit model 133A) routinely used during surgical procedures in an ultra clean orthopaedic theatre; and from the distal end of the hose. The last study (Zink 1993) was used as indirect evidence of the risk of infection. The study simulated a surgical site with healthy male volunteers (indirect population). Bacterial culture plates were fastened to patients' abdomen at the start of each trial period.

- One prospective study (Huang 2003) investigated whether use of the Bair Hugger® FAW during prolonged vascular surgery may lead to increased bacterial contamination of the surgical field by mobilisation of the patient's flora.

In the case reports and case series, information about gender was available from all but one study (Marders 2002). There were more men (85%) than women (15%) among the twenty patients reported. The mean age for all studies except for one study (Hemmerling 2002) was 62 years, with a range of 42 to 80 years. Only one study stated that it was carried out in an African-American patient (Zukowski 1998) while the others did not state the ethnicity. Bair Hugger® was the most frequently reported FAW device in these studies.

Warming systems
- Forced-air warming systems were used in fifteen studies:
  - Bair Hugger® active warming system was used in four studies to cover the upper body (Zuokumor 2004; Huang 2003; Ayala and Coe 1997; Guignard 2000) and in other three studies to cover both head and lower body areas (Hemmerling 2002; Marders 2002; No authors listed 1990). In two more studies, Bair Hugger® was compared with electric heating pad blanket (Ng 2006) and with electric over blanket (Camus 1997).
  - Forced air convection warming systems were used in five other experimental studies to detect potential risk of infection (Baker 2002; Tumia 2002; Avidan 1997; Sigg 1999; Zink 1993) one of which was included as indirect evidence (Zink 1993).
  - Another system, type not stated, was used in one study which used FAW to cover the upper body (Frolic 2001)
- Radiant heat was used in two studies:
  - The Suntouch (model PW820. Fisher and Paykel appl) was applied on the right forearm of a patient in one report (Batistich 2006)
  - The Emerson system was applied on upper body areas in another study (Zukowski 1998)
- A water garment was used in one study:
  - MTRE (advanced technologies) was applied to upper and lower body areas (legs, thoracic and sacral) (Gali 2003)
- Fluid warming was used in one study:
  - Infusion warming device Belmont (FMS 2000) was used for rapid inductive warming of intravenous fluids (Husser 2004)
- Various warming systems were reported in two observational retrospective studies (Kressin 2004; Cheney 1994).

RESULTS

1. Observational retrospective insurance study

An observational study reported on the American Society of Anaesthesiologists (ASA) closed claims project database, a collection of closed malpractice claims, in which 89% of 3,000 claims were made from 1977 to 1987 (Cheney 1994). The study excluded dental damage claims. Of the 3,000 claims, 28 patients presented burns as adverse anaesthetic outcomes. Only 8 (29%) of these were related to warming equipment (electrically powered equipment to treat hypothermia or provide localised heat) and 20 (71%) were from heated materials (warming oven used for generalised or local warming). Characteristics of included studies are detailed in Appendix C.

The rationale for application of heat varied among the studies, from the prevention/treatment of hypothermia, to the maintenance of body temperature in major surgical procedures, to the treatment of intravenous (IV) infiltration or simple warming of patients.

All burns involved patients undergoing long operations. The burns seemed to be caused by a combination of heat and pressure over bony prominences. Almost three-quarters of the burns (20 of 28) were due to IV bags or bottle heated materials (Figure 1), 85% (17) of which occurred in young and healthy women (mean age: 38±17 SD and ASA I-II). The majority of these events (N=10) occurred in women undergoing gynaecologic surgical procedures and the rest were in orthopaedic (N=5) or hernia (N=2) surgeries. Five patients presented burns of second and third degree. The standard of care for this category is noted as less than appropriate for all but one bag/bottle induced burn.

Burns due to electrically powered warming equipment (Figure 2) represented only one third (29%) of the total burns from warming related devices (7 patients). Five of these were due to circulating water blankets: in one, the device was defective and in the others, the patients were over 60 years. Most had an ASA physical status of III-IV and underwent major surgical procedures. Standard care was noted as appropriate in all but one of the cases.

Another study (Kressin 2004) presented an update of the above data. By 2004, the total claims in the ASA Closed Claims Project database had raised to 6,449 of which, 145 were burn injuries. Of these, 84 burns were due to warming devices (N=33) and heated material (N=51) which accumulated since 1985. New data added 31 burns due to warming devices and 33 burns due to IV bags or bottles since previously reported (Cheney 1994). Again in this study, the most common cause of burns was due to heated material followed by warming devices.

Heating blankets were the most common cause (N=16) of burns within warming devices followed by heating pads (N=10). Of the 31 burns caused by warming devices, 16 were located on buttocks, thighs, legs and feet. Location for the other 15 burns was not reported. Of the 33 burns caused by heated material, 15 were located on axila or trunk. There were 18

cautery burns including direct burning from the cautery or burns secondary to a faulty grounding pad. It was not specified whether the cautery burns are from electric blanket or another device.

Of the total 145 claims, nine were burns causing permanent or disabling injuries. Four were attributed to warming blankets placed on abdomen, buttocks, legs and feet. Out of the four, three happened during vascular surgeries. Another burn caused by warming blanket occurred in a child who presented an abdominal burn with subsequent cardiac arrest. There was one death in the 145 burn claims which occurred due to an airway fire during laser vaporisation of tracheal stenosis with use of 100% oxygen. Claims for 82% of the burns by warming devices and 80% of the burns by heated materials (IV bags or bottles) were paid. The largest payments were for cautery burns and the least paid claims were for burns caused by non warming devices.

There were a few discrepancies with the data reported in this study. The study states that 23% of burns equates to 33 burns. However, when the types of warming devices causing these burns are outlined, the figure is actually 35.

2. Forced-air warming
RCTs
One RCT was conducted in China (Ng 2006) on the efficacy of warming devices to maintain normothermia. The study did not report any adverse effects, but discussed the potential for adverse effects of warming devices. Ng (2006) compared FAW (Bair Hugger®; Augustine Medical model 500/OR, Praire, MN) versus an electric heating pad (Operatherm 2002). The study suggested that, in comparison to FAW, the electric heating pad would be expected to be easier to disinfect since it does not have a hose or hidden spaces, consisting only of a warming unit, an electric cable and a heating pad.

The authors also suggested that careful consideration should be given to potential sources for the increase of bacterial colonisation and contamination when using FAW, including:
- Re-use on other patients
- Difficulty in cleaning the hose and both the interior and exterior of the warming units
- Temperature and air stream of the warming units.

Case reports and case series
One study reported a partial and full thickness burn of 2% of the surface and suggests that this was indirectly caused by the FAW device (Zuokumor 2004). FAW raised the temperature of a fluid filled axillary roll (normal constant temperature = 37°C). Patient's weight pressure on hypothermic and vasoconstricted skin over time may have contributed to skin heat transfer. The burn needed debridement and skin grafting.

Another study related to the risk of bispectral index (BIS) signal alteration and thus misinterpretation of BIS values. In a case series, 5 cases had falsely increased values and 5 had falsely decreased values linked with the concomitant use of upper-body Bair Hugger® warming blankets (Hemmerling 2002). The high BIS indices did not match the clinical assessment of the depth of anaesthesia and there was no indication of malfunctioning. Artefacts and interference with other electrical devices may have influenced BIS alterations and interpretation.

This case series is supported by a previous report in which the use of FAW blankets altered the BIS signal (Guignard 2000). This third study investigated the effect of different settings of the FAW device. When the FAW was on, the BIS increased; when the Bair Hugger® unit was on but disconnected from the blanket, BIS returned to values of <60. Air circulation, due to vibration of head wires, may have caused an artefact not visible on the raw electroencephalographic trace. The study concluded that potential interference from FAW systems must be taken into account when interpreting BIS.

Another case report described the risk of increased systemic fentanyl levels which led to overdose symptoms when a transdermal fentanyl patch (TFP) was exposed to heat by an upper body warming blanket in a 57 year old woman undergoing open reduction and internal fixation of a right tibia stress fracture (Frolich 2001). It is suggested that exposure of the patient's skin which had a temperature of 34.9°C to the heating blanket increased cutaneous skin perfusion. This resulted in an increase in the systemic absorption of fentanyl from the intracutaneous fentanyl depot, leading to higher fentanyl levels and symptoms of opioid overdose. Although the United States Food and Drug Administration (FDA) approved the use of TFP in 1991, its labelling warns on the exposure of the TFP site to direct external heat sources but no specific recommendations are provided for its use intraoperatively.

In an earlier study, the use of FAW gave a risk of tracheal tube obstruction and potential damage to the patient's lungs (Ayala and Coe 1997). The tube was moved from its original vertical position after 35 minutes of surgery and high and low thresholds of pressure from the ventilator alarm were set too wide to the peak inflation pressure. Consequently, ventilation peak inflation pressures rose (from 18 to 35 cm H_2O) and the tracheal uncut polyvinyl chloride tube became soft. The problem was corrected by cutting the tube so none of it was outside the mouth and not exposed to a temperature of 40°C. The study concluded that the use of PVC is not recommended when a FAW system is used and tubing must be supported adequately. The high and low thresholds of the pressure sensitive ventilator alarms should be set close to the peak inflation pressure to give immediate warning of any obstruction.

Another report describes two cases of burns with the use of the FAW Bair Hugger® system (Augustine Medical) (No authors listed, 1990, Health Devices). In the first case of burn injury, the wrong side, i.e. the top layer (plastic side) of the blanket was placed in contact with the patient's skin. Consequently, the blanket flexed in the opposite direction with its middle channel covering legs and knees, causing burns. The second case involved a patient with severe vascular disease who developed a large blistered area due to incorrect use of blanket. The patient's left leg was covered with a blanket for 1.5 hours with the device operating at its maximum temperature. These two cases illustrate that:

- Maximum temperature is not safe in all circumstances, even when the device is used correctly.
- Direct contact of patient's skin with plastic heated to 120°F can cause thermal injury. The extent of injury will depend on the duration of contact with patient's skin.

The study recommends the use of FAW devices according to the manufacturer's directions and instructions.

Two additional cases acknowledged by the FDA as serious injuries due to free-hosing (when a blanket is not attached to the hose) have been reported (Marders 2002). The first was a surgical patient on whom the warm air was blown without attaching the blanket from the warming unit, leading to second and third degree burns to lower extremities. In the second, also a surgical patient, no blanket was attached to the hose. Instead, the hose was placed under the patient's blanket causing thermal injury and subsequent severe muscle necrosis and further above-the-knee amputation. Report of adverse events involving medical devices has been encouraged by the FDA in order to accurately identify problems with the devices and desirable patient outcomes.

Concerns regarding patient safety when using FAW devices have been addressed in a report (Augustine 2002) and a website (www.stophosing.com) as part of a campaign to raise clinicians' awareness about hosing. Both the risks associated with and the preventative measures for the improper use of these have been reported. It has also been explained that by not attaching the blanket to the hose, the warm air flow is concentrated on only one area of the patient's body for an extended period during surgical procedure, leading to traumatic thermal injuries, e.g. above mentioned cases by Marders (2002). Also, a blanket not properly put in place could consequently cause hosing. Following the manufacturer's directions on operating the units, the service manuals, printed instructions and labels on the devices are recommended as a way to ensure that patients are not harmed.

Experimental cross-infection reports

Four studies explored the potential of cross infection when using FAW devices.
One study (Avidan 1997) investigated whether:

- Two warming systems blow contaminated air
- The use of perforated blankets could prevent the detection of contamination
- Microbial filter on the end of the hose of warming device filters out organisms.

A vascular operating theatre was the site of experiments. Although the authors noted that microbial filters are regularly changed and that detachable hoses are regularly decontaminated, there seems to be a low risk of infection. The study detected a potential source of nosocomial infection that may be due to colonisation in the machines distal to the filters. It is stated that normally filters should protect against entrained bacteria and fungus but microbial pathogens were detected in about 50% of the FAW tested devices when air was sampled directly and without perforated blankets. Conversely, the use of perforated blankets in the same experiment produced no contaminated sampled air. This study recommended that:

- FAWs are used only when attached to perforated blankets
- Microbial filters are changed as the manufacturer specifies
- Detachable hoses are sterilised regularly
- Hoses are incorporated into the design of the warmer to reduce contamination.

A second study investigating the hazards of intraoperative FAW obtained similar results (Baker 2002). Growth of bacteria was found in swab samples from the exterior and interior of the warmer and from the distal end of the hose, suggesting that risk assessment should be undertaken before using FAW. Although the perforated blanket was not analysed as a microbial filter, the study suggested that even a small number of non-pathogenic organisms from contaminated air may come into contact with the surgical area and cause serious complications. The study recommends and advises on:

- The intraoperative use of sealed unit machines fitted with appropriate microbial filters based on thorough risk assessments
- Following the manufacturers instructions for changing the microbial filters and for the use of blankets
- Paying special attention to ensure that blankets are properly sealed to patient's skin in order to prevent air contamination.

Another study also discussed the re-use of disposable blankets for other patients, suggesting that bacterial contamination triples after use (Sigg 1999). In this study, FAW of used and new commercial blankets were potential sources of nosocomial infection.

Another study in this category investigated the possible sources of contamination in laminar airflow operating theatres (Tumia 2002). This found that the use of warm air convection heaters increased the number of colonies in the ultra clean air but this was noted to be not clinically significant.

A comparative randomised cross-over study (Zink 1993) was included as indirect evidence to the risk of infection. It raises the concern on the contribution of convective warming devices (CWD) to high air flows in close proximity to the patient, consequently leading to a potential of air-borne bacterial contamination when convective air coverlets are not used as recommended by the manufacturer's instructions. The study hypothesised that use of convective warming therapy (CWT) is unlikely to increase a patient's risk for wound contamination during surgery. A surgical site was simulated with healthy male volunteers (indirect population) not taking antibiotics within a month before the study who had bacterial culture plates fastened to their abdomen at the start of each trial period (see Appendix C for details). Two groups of randomly divided subjects were created:

- Control-therapy: convective cover in place but not inflated for the first 2 hour period with blowers operational setting for the latter 2 hour period
- Therapy-control: convective cover in place initially on for the first 2 hour period with blowers operational setting off the latter 2 hour period.

The authors noted that FAW with lower body commercial blanket did not increase the potential for air-borne bacterial wound contamination and infection in the operating room. On the analysis of bacteria, the number of colony-forming units recovered from operating rooms was not increased by forced air blowers. There also were no signs of the worst pathogens for serious wound contamination and infection (staphylococcus aureus). This may be due to several factors:

- The singular use of warming coverlets
- The size of the floor mounted blower had a filter of an air intake much smaller (0.2 μm) than the average size of bacteria carrying particles
- An adhesive strip on the warming cover which was applied at the waist helping to direct air flow away from the surgical site and personnel.

Huang (2003), a prospective study, investigated the potential for prosthetic material infection with prolonged exposure of the patients undergoing aortic surgery with prosthetic graft insertion to the exhaust of the warming blanket Bair Hugger®, possibly by mobilising their resident skin organisms into the theatre atmosphere then into the surgical field. Vascular surgery was performed in a standard positive pressure theatre. Air samples from theatre atmosphere, around the axillae and swab specimens were taken from the warming unit, hose and from the wound edges from the abdomen. Readings were taken when the warming blanket was first applied and at the end of the operation. None of the patients developed postoperative wound or prosthetic infections during a 6 month follow-up period. Using the Bair Hugger® patient warming system during prolonged abdominal surgery does not increase bacterial contamination of the operating theatre atmosphere and is therefore unlikely to cause contamination of the surgical field.

2. Electric blankets

RCTs

In another RCT study, an electric blanket group using Electroconcept brand for legs to pubis (model CB2) and for head, trunk and arms (CB3) is compared to a usual case control group (Camus 1997). There were no thermal skin lesions detected but the skin temperature under the blankets reached 38.4°C. Although this temperature is under the limit (41°C) allowed by the international standards to avoid thermal lesions, the study speculates on the potential adverse effects of using electric blankets. These include:

- Electrical hazards as a result of insufficient electric insulation, outer sheath breakage or cutting by surgical instruments
- Risk of electrocution to the patient, surgeon or anaesthetist
- Burns due to the inefficient heat transfer resulting from limitation of skin warming to guarantee thermal safety.

3. Radiant heat

Case reports

Two studies reported patients with burns caused by the use of radiant heat systems. One applied radiant heat (Suntouch model PW820 of intra Fisher and Paykel appliances) to an 80 year old patient undergoing right hephrectomy (Batistich 2006). The patient's arm burned when placed too close to the device.

A second report in which radiant heat was also applied described a patient for whom the device (Emerson warming light) caused second degree burns with skin blisters (Zukowski 1998). It was determined that nursing staff inadvertently pushed the light against the bed during patient care manoeuvres leaving the light against the bed rail 32cm from the patient. The authors concluded, from further investigations, that at 32cm from the patient, warming lights can cause tissue compromise after 30 minutes for a focused beam and between 45 and 60 minutes of a defocused beam. The study emphasises to clinicians the importance of proper patient positioning during postoperative care in the recovery room and ward when using warming light therapy.

4. Water garment

Case reports

One study using a circulating water garment (ThermoWrap MTRE Advanced technologies) reported a skin injury from second degree burns in a 67 year old male undergoing liver transplantation (Gali 2003). The study found it difficult to discern the reasons for the burn. Discussion of contributing factors included pressure and heat or a combination of these and the patient's risk factors (age, poor nutritional status, low serum albumin level and prolonged

surgery). The study recommended that clinicians should consider circulating water garments to be a potential risk for prolonged surgeries.

5. Fluid warming

Case reports

Finally, there is one report on the risk of dramatic haemodynamic damage caused by thermal injury associated with malfunctioning of a Belmont FMS 2000 inductive fluid warming device (Husser 2004). A 42 year old male patient undergoing highly invasive orthopaedic surgery presented with hypotension (from 110/50 to 50/30 mmHg) and tachycardia (from 197 to 130 beats per min). Overheating caused damage and disfiguring of the toroid element of this device during rapid infusion. The study drew attention to the potential physiological damage due to thermal-mediated leukocyte free-radical production, complement activation and release of vasoactive mediators (prostaglandins, leukotrienes, interleukins, cytokines, etc) from thermally lysed or degranulated leukocytes. Generally, the temperature within the toroid itself is not monitored suggesting the possibility that formed elements from the transfused blood were exposed to non-physiological extreme temperatures (≥100°C) lysing and releasing vasoactive mediators, resulting in patient injury.

Conclusions

This review identifies some of the risks and adverse effects reported in the literature associated with warming devices. The most common adverse effects were burns and infection. Although many potential sources of adverse effects can be identified, there does not seem to be empirical support that indicates that warming systems increase the risk of infection if properly used. FAW systems are naturally built to eliminate bacteria. Similarly, FAW systems if properly used by following the manufacturer's instructions could prevent clinicians from causing any harm or injury to their patients.

Figure 1: Cheney (1994), sources of burns from heated material (IV bags and bottles)
Of 20 patients, 18 had burns, five of which were of second and third degree. 15 were due to generalised warming and 3 were due to local heat.

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18 burns caused by bags & bottles

15 by generalised warming ⟷ 5 patients with burns of 2nd and 3rd degree ⟷ 3 by local heat on patient's skin

Rationale for application of heat:
5 to treat hypothermia
3 to maintain body temperature
7 to just warm patients

Placed by
5 by anaesthesiologist
1 by certified registered nurse anaesthetist
1 by operating room nurse
8 unknown

Rationale for application of heat:
2 treated for sequealae of infiltrated iv infusion
1 to ease venous dilatation and placement of an iv catheter

Placed by
1 by anaesthesiologist
1 by operating room
1 unknown

18

Figure 2: Cheney (1994) sources of burns from warming devices
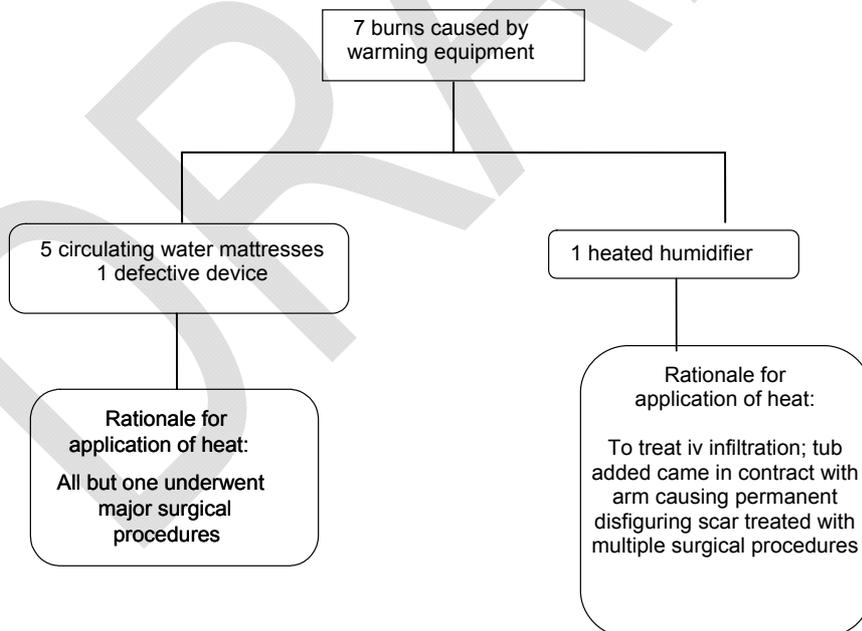
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7 burns caused by warming equipment

5 circulating water mattresses
1 defective device

1 heated humidifier

Rationale for application of heat:
All but one underwent major surgical procedures

Rationale for application of heat:
To treat iv infiltration; tub added came in contract with arm causing permanent disfiguring scar treated with multiple surgical procedures

1 **10.5 FLUIDS**

2 **Characteristics of clinical studies included in the review (Appendix C)**

3 Twenty studies are included in this review (Camus 1996; Cooper 1994; Dyer 1986; Ellis-Stoll

4 1996; Hasankhani 2005; Jaffe 2001; Kelly 2000; Kurz 1995; Monga 1996; Moore 1996;

5 Motamed 1998; Muth 1996; Patel 1996; Patel 1997; Pit 1996; Schmied 1996; Smith 1998;

6 Smith 1998b; Steinbrook 1997; Zhao 2005). The excluded studies are listed in Appendix E.

7

8 A total of 854 patients were included in the review. Nine studies (Cooper 1994; Camus 1996;

9 Moore 1996; Monga 1996; Patel 1997; Smith 1998; Steinbrook 1998; Kelly 2000; Zhao 2005)

10 had fewer than 20 patients in each arm.

11

12 **Participants**

13 The age range of participants across studies (where given) ranged from 18 to 89 years, with

14 the mean age (where given) ranging from 30 to 72 years.

15

16 One study was conducted in the UK (Cooper 1994), nine studies in the USA (Ellis-Stoll 1996;

17 Monga 1996; Moore 1996; Patel 1996; Patel 1997; Steinbrook 1997; Smith 1998; Smith

18 1998b; Jaffe 2001); two studies in Austria (Kurz 1995; Schmied 1996); one study in Canada

19 (Motamed 1998); one in Germany (Muth 1996); one in France (Camus 1996); one study in the

20 Netherlands (Pit 1996); one in Australia (Dyer 1986); one in China (Zhao 2005) and one study

21 was conducted in Iran (Hasankhani 2005). In one study (Kelly 2000) it was unclear in which

22 country the study was conducted.

23

24 One study included patients with ASA I status (Hasankhani 2005), two studies (Camus 1996;

25 Kelly 2000) reported ASA I and II grade, and one study included patients with ASA III (Muth

26 1996). Six studies (Kurz 1995; Patel 1996; Patel 1997; Steinbrook 1997; Smith 1998; Smith

27 1998b) included patients with ASA I, II and III status. ASA status was not reported in the

28 remaining studies.

29

30 A range of procedures were undertaken. Four studies included patients undergoing

31 transurethral resection of the prostate (Dyer 1986; Monga 1996; Pit 1996; Jaffe 2001); three

32 undergoing abdominal surgery (Camus 1996; Steinbrook 1997; Zhao 2005); three in

33 gynaecological surgery (Cooper 1994; Moore 1995; Smith 1998); two studies in orthopaedic,

34 gynaecological or general surgery (Patel 1997; Smith 1998b); colon surgery (Kurz 1995);

35 laparoscopic cholecystectomy (Ellis-Stoll 1996); orthopaedic or gynaecological surgery (Patel

36 1996); hip arthroplasty (Schmied 1996); colorectal surgery (Motamed 1998); knee arthroscopy

37 (Kelly 2000); orthopaedic surgery (Hasankhani 2005); and abdominal aortic aneurysm (Muth

38 1996).

39

Type of surgery was stated as elective in 12 studies (Cooper 1994; Kurz 1995; Camus 1996; Muth 1996; Patel 1996; Patel 1997; Smith 1998; Smith 1998b; Moore 1997; Motamed 1998; Hasankhani 2005; Zhao 2005) and not stated in the remaining studies.

Mean duration of surgery ranged from 30 to 60 minutes in two studies (Kelly 2000; Pit 1996); 1 to 3 hours in twelve studies (Camus 1996; Ellis-Stoll 1996; Moore 1996; Patel 1996; Patel 1997; Smith 1998; Smith 1998b; Schmied 1996; Motamed 1998; Jaffe 2001; Hasankhani 2005; Zhao 2005); more than 3 hours in six studies (Dyer 1986; Kurz 1995; Muth 1996;Patel 1996; Patel 1997) and not stated in the remaining studies.

Patients underwent general anaesthesia in ten studies (Kurz 1995; Camus 1996; Muth 1996; Patel 1996; Schmeid 1996; Smith 1998; Smith 1998b; Moore 1997; Patel 1997; Hasankhani 2005); regional anaesthesia in three studies (Dyer 1986; Pit 1996; Kelly 2000); mixed anaesthesia (epidural or general) in one study (Motamed 1998); general anaesthesia or combined epidural-general anaesthesia in one study (Steinbrook 1997); general or regional anaesthesia in one study (Monga 1996) and not stated in the remaining studies.

Type of premedication, dose and method of delivery were as follows:
- Diazepam (10mg) orally (Kurz 1995; Schmeid 1996: 1 to 2 hours before surgery);
- IV midazolam was administered to all patients just before leaving the preoperative holding area (Kelly 2000);
- Midazolam and fentanyl IV (Steinbrook 1997: 1 to 4mg and 100 to 250µg respectively; Smith 1998: 2mg and 100 to 200µg respectively);
- Atropine (0.2 to 0.4mg) (Hasankhani 2005);
- Hydroxyzine (100mg) orally 1 hour before surgery (Camus 1996);
- Flunitrazepam (1 to 2mg) orally (Muth 1996);
- Fentanyl, midazolam (Patel 1997);
- No premedication was administered in one study (Motamed 1998).

The remaining studies did not report on premedication.

Methodological quality of included studies (Appendix D)
The method of randomisation was adequate in seven studies (computer generated random numbers table: Kurz 1996; computer generated codes: Schmeid 1996; random numbers table: Patel 1996; Moore 1997; Smith 1998b; Kelly 2000; coin toss: Steinbrook 1997; Hasankhani 2005); inadequate method of randomisation (according to the day of surgery) in one study (Muth 1996) and unclear in the remaining studies. Allocation concealment was partially adequate in one study (sequentially numbered opaque envelope: Schmeid 1996), likely to be inadequate in one study (Muth 1996) and not stated in the remaining studies. In one study

1   (Cooper 1996) with 14 patients it was unclear how many patients were randomised into each
2   group; an equal distribution was assumed.
3   In four studies observers assessing shivering were blinded to the treatment group (Camus
4   1996; Motamed 1998; Hasankhani 2005; Zhao 2005). In two studies (Patel 1996; Smith 1998),
5   nurses recording postoperative data were blinded to the patient group. In one study (Kurz
6   1995) nurses and physicians administering pain management and the observer assessing
7   shivering were blinded to the patients' group assignment and core temperatures. In one study
8   (Motamed 1998) patients and assessors were unaware of the group allocation. One study
9   (Jaffe 2001) stated it was a double-blind study.
10
11   One study (Schmeid 1996) reported conducting a power calculation. A pilot study indicated
12   that in order to detect a significant increase in blood loss induced by hypothermia (at 80%
13   power; p=0.05 two tailed), 60 patients were required.
14
15   Two studies (Patel 1996; Kelly 2000) reported that more than 20% of the patients dropped out
16   from any one group or overall:
17   •   Patel (1996) reported that 10/49 patients were excluded from the analysis. There were
18   7/25 (28%) in the Flotem II group and reasons for exclusion included: warming mattress
19   used throughout surgery (n=3); failure to use warmer (n= 3); closed head injury with
20   perioperative temperature above 38.5°C (n=1). In the Hotline group there were 3/24 drop
21   outs; reasons for exclusion included: failure to use the warmer (n=2); surgery lasting 28
22   minutes (n=1).
23   •   Kelly (2000) reported that 4/24 patients were excluded from the analysis. In the warming
24   group 3/9 (33%) dropped out; reasons were: tourniquet inflation required (n=2); warming
25   (n=1). In the control group 1/11 patients dropped out because warming was required and
26   this patient was not included in the analysis.
27
28   Five studies (Steinbrook 1996; Moore 1997; Patel 1997; Smith 1998b; Hasankhani 2005)
29   reported dropouts fewer than 20%:
30   •   In Steinbrook (1996), 3/24 patients were excluded from the analysis due to deviations
31   from experimental protocol, changes in anaesthetic or surgical procedures or technical
32   problems with equipment.
33   •   In Moore (1997), 6/35 patients did not require irrigation fluid and were treated as a
34   separate group. It is unclear into which groups these patients were originally assigned.
35   •   In Patel (1997), 2/15 patients were excluded from the treatment group because: surgery
36   lasted more than an hour (n=1); fluid warmer malfunction (n=1).
37   •   In Hasankhani (2005), 5/60 patients were excluded following randomisation: use of
38   epidural anaesthesia (n=3) and use of midazolam as premedication (n=3).
39   •   In Smith (1998b), reported 5/61 patients were excluded after randomisation. In the
40   intervention group one patient (n=1/31) was excluded because the surgeon requested the

1 convective warmer was turned off; in the control group, 4/30 patients were excluded:
2 anaesthesiologist's decision to use enflurane instead of isoflurane (n=1); intraoperative
3 bleeding and decision to use fluid warmer (n=3).
4
5 One study (Schmied 1996) indicated an intention to treat analysis.
6
7 Comparabilities for the baseline core temperatures (Figure 1) and the volume of infused fluids
8 (Figure 2) are shown below.
9
10 **Figure 1: Baseline core temperature**

Review: IPH Fluid warming
Comparison: 09 Warmed fluids vs no warming/RT fluids
Outcome: 01 Core temperature- baseline

Study or sub-category	N	Treatment Mean (SD)	N	control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 Baseline core temperature-GA							
Camus 1996	9	37.00(0.30)	9	36.90(0.30)		2.97	0.10 [-0.18, 0.38]
Cooper 1994	7	36.37(0.10)	7	36.01(0.23)		6.62	0.36 [0.17, 0.55]
Hasankhani 2005	30	37.03(0.16)	30	37.03(0.20)		27.20	0.00 [-0.09, 0.09]
Jaffe 2001	29	36.88(0.39)	27	36.78(0.38)		5.62	0.10 [-0.10, 0.30]
Kelly 2000	12	36.10(0.13)	12	36.40(0.10)		26.54	-0.30 [-0.39, -0.21]
Kurz 1995	39	37.30(0.40)	35	37.20(0.40)		6.86	0.10 [-0.08, 0.28]
patel 1996	24	37.00(0.49)	25	37.20(0.10)		5.72	-0.20 [-0.40, 0.00]
Patel 1997	16	36.60(0.40)	19	36.90(0.44)		2.95	-0.30 [-0.58, -0.02]
Schmied 1996	30	36.80(0.30)	30	36.90(0.70)		3.08	-0.10 [-0.37, 0.17]
Smith 1998	18	37.00(0.40)	20	36.88(0.56)		2.42	0.12 [-0.19, 0.43]
Smith 1998b	30	36.60(0.55)	26	36.80(0.51)		2.96	-0.20 [-0.48, 0.08]
Steinbrook 1997	6	36.50(0.49)	9	36.20(0.90)		0.46	0.30 [-0.41, 1.01]
Zhao 2005	20	36.50(0.30)	20	36.50(0.30)		6.61	0.00 [-0.19, 0.19]
02 Baseline core temperature- Epidural-General							
Steinbrook 1997	5	36.50(0.45)	4	36.20(0.40)		100.00	0.30 [-0.26, 0.86]

-4   -2   0   2   4
Favours control   Favours treatment

12 NB: Scale -4 to 4
13

Review: IPH Fluid warming
Comparison: 09 Warmed fluids vs no warming/RT fluids
Outcome: 04 Baseline CT

Study or sub-category	SE (SE)	SE (fixed) 95% CI	Weight %	SE (fixed) 95% CI
Motamed 1998	0.2000 (0.1940)		100.00	0.20 [-0.18, 0.58]
Total (95% CI)			100.00	0.20 [-0.18, 0.58]

Test for heterogeneity: not applicable
Test for overall effect: Z = 1.03 (P = 0.30)

-1   -0.5   0   0.5   1
Favours usual care   Favours FAW+fluids

14
15

16 In one study (Ellis-Stoll 1996), baseline core temperatures were extracted from a graph, but
17 standard deviations were not provided; therefore, it is not included in Figure 1. In one study
18 (Muth 1996), baseline core temperatures were reported at the beginning of surgery. The core
19 temperature was above 35.5°C for both groups and there was no significant difference. We
20 note that baseline core temperature was measured at the sublingual site in study.
21
22 Baseline core temperature was not stated in the remaining studies.
23
24 The following studies had significant differences in baseline core temperature:
25 • 0.36°C higher for the actively warmed group (Cooper 1996);
26 • 0.30°C higher in the control group (Kelly 2000);
27 • 0.20°C higher for the active warming device 2 (countercurrent water heat exchange)

1   (Patel 1996);

2   • 0.30°C higher for the forced air warming group (Patel 1997).

3

4   Results for these studies will be considered only if the baseline difference is less than 20% of

5   the effect size.

6

7   **Figure 2: Differences in the volume of infused fluids**

Review: IPH Fluid warming
Comparison: 09 Warmed fluids vs no warming/RT fluids
Outcome: 02 Fluids-baseline

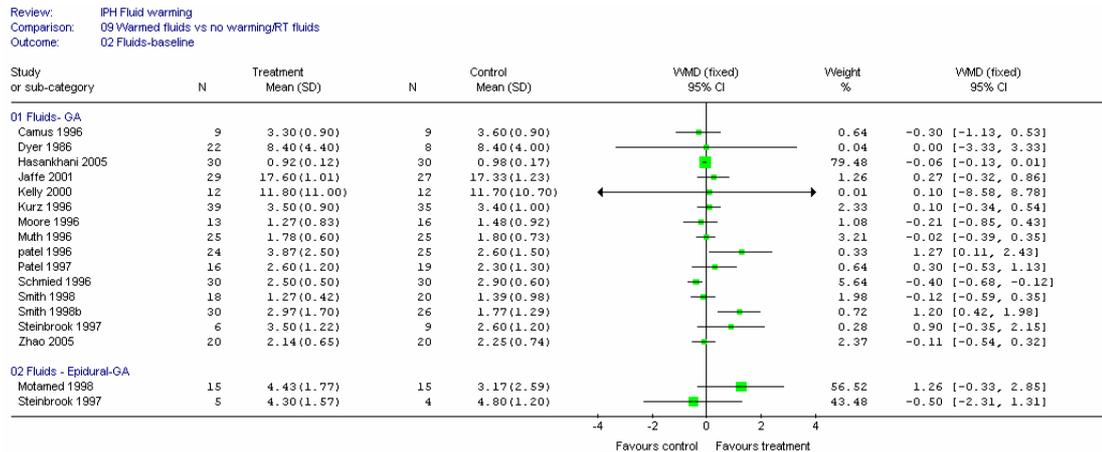| Study or sub-category	N	Treatment Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 Fluids- GA							
Camus 1996	9	3.30(0.90)	9	3.60(0.90)		0.64	-0.30 [-1.13, 0.53]
Dyer 1986	22	8.40(4.40)	8	8.40(4.00)		0.04	0.00 [-3.33, 3.33]
Hasankhani 2005	30	0.92(0.12)	30	0.98(0.17)		79.48	-0.06 [-0.13, 0.01]
Jaffe 2001	29	17.60(1.01)	27	17.33(1.23)		1.26	0.27 [-0.32, 0.86]
Kelly 2000	12	11.80(11.00)	12	11.70(10.70)		0.01	0.10 [-8.58, 8.78]
Kurz 1996	39	3.50(0.90)	35	3.40(1.00)		2.33	0.10 [-0.34, 0.54]
Moore 1996	13	1.27(0.83)	16	1.48(0.92)		1.08	-0.21 [-0.85, 0.43]
Muth 1996	25	1.78(0.60)	25	1.80(0.73)		3.21	-0.02 [-0.39, 0.35]
patel 1996	24	3.87(2.50)	25	2.60(1.50)		0.33	1.27 [0.11, 2.43]
Patel 1997	16	2.60(1.20)	19	2.30(1.30)		0.64	0.30 [-0.53, 1.13]
Schmied 1996	30	2.50(0.50)	30	2.90(0.60)		5.64	-0.40 [-0.68, -0.12]
Smith 1998	18	1.27(0.42)	20	1.39(0.98)		1.98	-0.12 [-0.59, 0.35]
Smith 1998b	30	2.97(1.70)	26	1.77(1.29)		0.72	1.20 [0.42, 1.98]
Steinbrook 1997	6	3.50(1.22)	9	2.60(1.20)		0.28	0.90 [-0.35, 2.15]
Zhao 2005	20	2.14(0.65)	20	2.25(0.74)		2.37	-0.11 [-0.54, 0.32]
02 Fluids - Epidural-GA							
Motamed 1998	15	4.43(1.77)	15	3.17(2.59)		56.52	1.26 [-0.33, 2.85]
Steinbrook 1997	5	4.30(1.57)	4	4.80(1.20)		43.48	-0.50 [-2.31, 1.31]

-4   -2   0   2   4
Favours control   Favours treatment

8

9   NB: Scale -4 to 4

10

11 In three studies the volume of infused fluids was significantly different:

12 • 1.27 litres (on 2.60 litres) higher in active warming device 1 group (countercurrent water

13   heat exchange fluid warmer) (Patel 1996);

14 • 0.40 litres (on 2.50 litres) higher in the control group (Schmied 1996);

15 • 1.20 litres (on 2.97 litres) higher in the actively warmed group (Smith 1998b).

16

17 The volume of infused fluids was not stated in four studies (Cooper 1994; Ellis-Stoll 1996;

18 Monga 1996; Pit 1996).

19

20 In one study (Motamed 1998), the body weight was significantly higher in the control group

21 and in one study (Patel 1996) the mean age was significantly higher in group 1

22 (countercurrent water heat exchange fluid warmer) group.

23

24 **Summary**

25 Overall, one study was considered to be at higher risk of bias (Muth 1996), which had an

26 inadequate method of allocation concealment. Six other studies were treated with caution, four

27 because of differences in baseline core temperatures (Cooper 1996, Kelly 2000, Patel 1996,

28 Patel 1997), and three studies had differences in the volume of fluid infused (Patel 1996,

29 Schmied 1996; Smith 1998b). All of these studies were considered in sensitivity analyses, and

30 the studies with baseline differences were not included in the analyses unless the outcome

31 had an effect size at least 5 times that of the baseline difference.

Interventions

I. Intravenous fluid warming

A. Active fluid warming versus no fluid warming (room temperature fluids)

   i. Active fluid warming versus no fluid warming (room temperature fluids)

-   Warmed IV fluids versus room temperature IV fluids (Cooper 1994);

-   Warmed IV fluids (set point 42°C) versus room temperature fluids (Smith 1998);

-   Warmed IV fluids (flow rates and set point temperature at 3 settings) versus room temperature IV fluids (Hasankhani 2005);

-   Warmed IV fluids (37°C) versus room temperature IV fluids (21°C) plus prewarmed blood products (37°C) (Muth 1996)

   ii. Active fluid warming versus room temperature fluids (with active patient warming in both groups)

-   Actively warmed IV fluids (37°C) versus room temperature IV fluids plus electric blanket (40°C) in both groups (Camus 1996)

-   Actively warmed IV fluids (38°C to 39°C) versus room temperature IV fluids plus forced air warming (48.9°C) in both groups (Camus 1996).

B. Active fluid warming 1 versus active fluid warming 2

   i. Active fluid warming type 1 versus active fluid warming 2

-   Dry heat exchange fluid warmer versus concurrent water heat exchange fluid warmer (Patel 1997).

   ii. Active fluid warming type 1 versus active fluid warming 2 (with active patient warming in both groups)

-   Warmed IV fluid versus pre-warmed IV fluid (Ellis-Stoll 1996) + warmed blanket (upper body) in both groups.

C. Active patient warming + active fluid warming versus usual care

-   Upper body forced air warming (40°C) + actively warmed IV solutions (37°C) versus routine thermal care (Kurz 1995);

-   Lower body forced air warming (42 to 43°C) + actively warmed IV solutions including blood (39°C) versus cotton sheet (Zhao 2005);

-   Upper body forced air warming(high) + warmed IV fluids (37°C) versus usual care (Schmied 1996);

-   Forced air warming (set to maintain core temperature near 37°C)+ actively warmed IV solutions (37°C) versus routine thermal care (Steinbrook 1997) (general; epidural-general anaesthesia);

- Upper body forced air warming + actively warmed IV fluids (37°C) versus usual care (Motamed 1998) (epidural-general anaesthesia).

II. Irrigation fluid warming

A. Irrigation fluid warming versus no warming (room temperature fluids)

   i. Passive fluid warming versus no warming (room temperature fluids)

- Pre-warmed saline irrigation fluid (40°C) versus room temperature saline irrigation fluid (Kelly 2000);
- Pre-warmed glycine irrigation fluid (37°C) versus room temperature glycine irrigation fluid (Dyer 1986).

   ii. Active fluid warming versus no warming (room temperature fluids)

- Actively warmed irrigation fluid (>36.8°C) versus room temperature irrigation fluid (Pit 1996)

   iii. Active or passive fluid warming versus no warming (room temperature fluids)

- Actively warmed irrigation fluid (37°C) or passively warmed (incubator) fluid (35°C) versus room temperature irrigation fluid (Monga 1996).

   iv. Active fluid warming versus room temperature fluids (with active patient warming in both groups)

- Warmed irrigation fluid (33.1°C) versus room temperature irrigation fluid plus warmed blanket in both groups (Jaffe 2001);
- Warmed irrigation fluid (39°C) versus ambient temperature irrigation fluid (20 to 22°C) plus heating blanket in both groups (Moore 1996).

III. Other comparisons

A. Thermal insulation + Passive fluid warming versus usual care

- Reflective blankets plus passively warmed fluids (37°C) versus usual care

B. Thermal insulation + active fluid warming versus active patient warming

- Aluminium (Thermadrape) blankets, head covers & leggings plus actively warmed IV fluids (42°C) versus Forced air warming plus room temperature IV fluids (Patel 1997)
  - This comparison changes two variables at once (FAW /thermal insulation and temperature of IV fluids).

Primary outcomes

Four studies (Muth 1996; Patel 1997; Smith 1998; Smith 1998b) recorded the number of patients with IPH, but most measured the core temperature at different times. For this outcome, an increase of 0.5°C over the control group temperature was considered to be

clinically significant for a control group temperature above 36°C and a difference of 0.25°C was considered to be clinically significant for control group temperatures below 36°C.

Core temperature was measured:

- During the intraoperative period (Cooper 1994; Kurz 1995; Camus 1996; Ellis-Stoll 1996; Patel 1997; Motamed 1998; Smith 1998; Smith 1998b; Jaffe 2001; Hasankhani 2005; Zhao 2005);
- In PACU (Kurz 1995; Patel 1997; Steinbrook 1997; Smith 1998; Smith 1998b; Kelly 2000).

Other outcomes were:

- Shivering (Cooper 1994; Camus 1996; Patel 1997; Steinbrook 1997; Motamed 1998; Smith 1998; Smith 1998b; Hasankhani 2005; Zhao 2005);
- Blood loss (Schmied 1996; Zhao 2005);
- Thermal comfort (Kurz 1995);
- Extubation time (Zhao 2005);
- Thermal discomfort (Pit 1996);
- Pain (Kurz 1995; Motamed 1998).

Core temperature was measured at the following sites:

- Tympanic (Kurz 1995; Camus 1996; Ellis-Stoll 1996; Moore 1996; Patel 1996; Schmeid 1996; Patel 1997; Steinbrook 1997 (PACU); Motamed 1998; Smith 1998; Kelly 2000; Jaffe 2001; Zhao 2005);
- Oesophageal (Cooper 1994; Steinbrook 1997(intraoperative); Hasankhani 2005; Moore 1996; Smith 1998b*);
- Rectal (Pit 1996);
- Sublingual (Dyer 1986; Monga 1996).

  * Core temperature was measured at the sublingual site for the pre and postoperative periods.

RESULTS

The GDG originally decided to stratify only by presence/absence of comorbidities, trauma, and hyperthermia. Perioperative phases were also to be considered separately, as were intravenous and irrigation fluids.

However, a post-hoc decision was made to stratify by type of anaesthesia (general; regional; combined), as these were expected to have different mechanisms of action. The GDG also decided to combine active and passive forms of irrigation fluid warming because there was likely to be rapid delivery of these fluids.

Initially, the GDG decided to combine all comparisons of active fluid warming versus usual care, regardless of the presence of other active patient interventions.

I. Intravenous fluid warming

A. Active fluid warming versus no fluid warming (room temperature fluids)

A1. General anaesthesia

Five studies (Cooper 1994; Camus 1996; Smith 1998; Smith 1998b; Hasankhani 2005) compared the effectiveness of active IV fluid warming versus room temperature IV fluids. In one study (Camus 1996) patients in both arms received electric blanket set at 40°C and in one study (Smith 1998b) patients in both arms received forced air warming set at high setting (48.9°C) (Figure 3).

In four studies, patients underwent general anaesthesia (Camus 1996; Smith 1998; Smith 1998b; Hasankhani 2005) and type of anaesthesia was not stated in one study (Cooper 1994).

One study utilised a dry fluid warmer (Hasankhani 2005), three studies used a concurrent water heat exchange technique (Camus 1996; Smith 1998; Smith 1998b). One study did not state the type of fluid warmer (Cooper 1994). The temperature at which fluids were infused varied. Fluid warmers were set at the following temperatures: 37.5°C (Cooper 1994); 38 to 39°C (Smith 1998); 39.5°C (Hansankhani 2005); 40°C (Camus 1996); 42°C (Smith 1998b).

The volume of infused fluids was as follows (for the active warmed fluid and the room temperature groups respectively):
- 3.3 litre (SD 0.9) versus 3.6 litre (SD 0.9) (Camus 1996);
- 1.27 litre (SD 0.42) versus 1.39 litre (SD 0.98) (Smith 1998);
- 2.97 litre (SD 1.7) versus 1.77 litre (SD 1.39) (Smith 1998b);
- 0. 918 litre (SD 0.12) versus 0.984 litre (SD 0.17) (Hasankhani 2005).

The volume of infused fluids was not stated in one study (Cooper 1996).

Flow rates of infused fluids were as follows (in some cases these were calculated from the mean weight and flow rate):
- 8 to 10ml/kg/h (Camus 1996);
- 11 to 20ml/kg/h (Smith 1998);
- 6 to 11mg/kg/h (Hasankhani 2005).

In two studies (Cooper 1994; Smith 1998b) the flow rates were not stated.

The type of IV fluids varied. In one study patients received sterile 1.5% glycine solution (Cooper 1994); Ringer's solution (Hasankhani 2005) and not stated in the remaining studies.

In one study (Cooper 1994) we note that there is a baseline difference in core temperature (0.36°C higher in the group assigned to active fluid warming). Results from this study will be considered only if the baseline difference is less than 20% of the effect size.

We note that in one study (Cooper 1994) it was unclear whether the error bars represented standard deviations or standard error means. The study provided the p value (p=0.05) for the change in temperature for the warmed group from baseline to 20 minutes. We extracted the mean temperature from the graph at baseline and at 20 minutes (p=.02) which confirmed that the error bars represented the standard deviations.

We note that in one study (Hasankhani 2005) in which data were extracted from graph the authors stated that the error bars denote standard deviations and the difference was statistically significant at p<0.05. However, the p values we obtained were much different (p<0.0001). As the reliability of the graph was questionable, we opted to use the standard deviation (0.50) reported in the text for the final core temperature for all intraoperative temperature measurements. This assumption will be explored in a sensitivity analysis.

Results for Muth (1996) were considered in sensitivity analyse because the method of randomisation was inadequate.

1. Incidence of hypothermia at the end of surgery

Three studies (Muth 1996; Smith 1998; Smith 1998b) with patients reported the number of patients with a core temperature less than 35.5°C (Muth 1996; Smith 1998) or less than 36°C (Smith 1998b) at the end of surgery. The results for Smith (1998b) are not included as warming was ceased for n=10/30 and n= 3/26 patients in the intervention and control groups, respectively and it was unclear if these patients were included in the analysis.

The results for Muth (1996) was considered in a sensitivity analysis (inadequate method of randomisation), The Peto odds ratio for the Muth (1996) study was similar to that for Smith (1998) and meta-analysis of the two studies in 88 patients showed no heterogeneity (I^2=0%, p=0.91). There was a significantly smaller incidence of hypothermia for the active fluid warming group (Peto OR 0.10 [95% CI 0.04, 0.24]). This corresponds to an NNT of 3 (95% 2, 4) for a control group rate range 35% to 64% (Figure 3).

Figure 3: Incidence of hypothermia; actively warmed IV fluids versus room temperature IV fluids; general anaesthesia
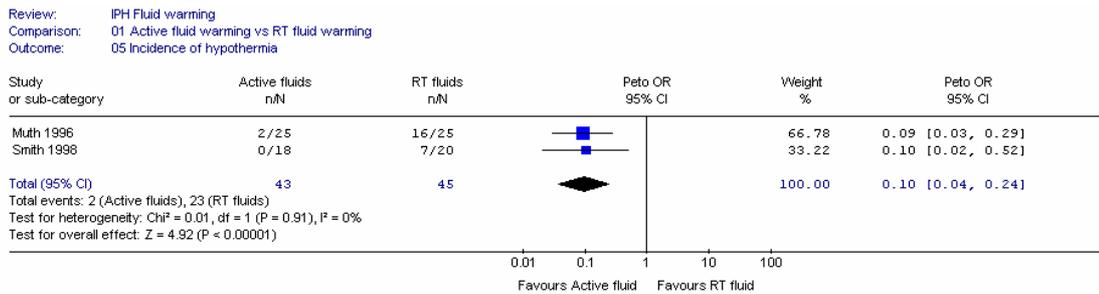
NB: Scale: 0.01 to 100

2. Core temperature at various intraoperative times

At 15 minutes, meta-analysis of three studies (Smith 1998; Smith 1998b; Hasankhani 2005) with 154 patients showed a significantly higher mean core temperature for the active fluid warming group: WMD 0.28°C (95% CI 0.11, 0.44) for a control group range of 35.6°C to 36.5°C. This difference is clinically significant. There was no heterogeneity (Figure 4).

At 30 minutes, meta-analysis of four studies (Cooper 1994; Camus 1996; Smith 1998; Smith 1998b; Hasankhani 2005) in 186 patients showed a significantly higher mean core temperature for the group receiving warmed fluids: WMD 0.40°C (95%CI 0.26, 0.54) for a control group temperature range of 35.5°C to 36.25°C. This is a clinically significant difference. There was no heterogeneity. For this duration, we excluded Cooper (1996) from the analysis as the effect size (0.48°C) is not more than 5 times the baseline core temperature difference (0.36°C).

At 60 minutes, meta-analysis of four studies (Camus 1996; Smith 1998; Smith 1998b; Hasankhani 2005) with 172 patients showed a significantly higher mean core temperature for the group receiving warmed fluids: WMD 0.38°C (95% CI 0.21, 0.54) for a control group range 35.8°C to 36.2°C. We note that in one study (Hasankhani 2005) for this time period we have used the final intraoperative core temperature (possibly at 60 or 70 minutes duration of surgery) as reported in the text.

At 2 hours, meta-analysis of two studies (Camus 1996; Smith 1998b) with 74 patients, showed a significantly higher mean core temperature for the actively warmed fluids group: WMD 0.49°C (95% CI 0.18, 0.81) for a control group temperature of 35.8°C to 35.9°C. This difference is clinically significant. The confidence interval is fairly wide.

At 3 hours, in one study (Camus 1996) with 18 patients the mean core temperature was significantly higher for the warming group: MD 0.72°C (95% CI 0.17, 1.27) for a control group temperature of 35.7°C. The difference is clinically significant, but the confidence interval is wide.

1   At 4 hours, in one study (Camus 1996) with 18 patients, the mean core temperature was
2   significantly higher for the warming group: MD 0.86°C (95% CI 0.11, 1.61) for a control group
3   temperature of 35.7°C. The difference is clinically significant, but the confidence interval is
4   wide.
5
6   **3. Core temperature at the end of surgery**
7   Five studies (Camus 1996; Muth 1996; Smith 1998; Smith 1998b; Hasankhani 2005) reported
8   the core temperature at the end of surgery. The mean duration of surgery was just over 1 hour
9   in two studies (Smith 1998; Hasankhani 2005), over 2 hours in one study (Muth 1996) and 6
10 hours in the other (Camus 1996) (Figure 4).
11
12 In one study (Smith 1998b) the mean duration of surgery was significantly longer by 68
13 minutes (p=0.01) for the warmed group compared to the control group which is likely to be
14 confounding. In addition, warming was ceased at 131 minutes (n=10/30) and 165 minutes
15 (n=3/26) in the intervention (forced air warming and warmed fluids) and control groups (forced
16 air warming and room temperature fluids) respectively. It was decided not to include this
17 outcome for the Smith (1998b) study.
18
19 The results for Muth (1996) were considered in a sensitivity analysis (inadequate method of
20 randomisation). The odds ratio for the Muth (1996) study was similar to that for Camus (1996).
21 There was no significant heterogeneity.
22
23 Meta-analysis of the four studies (Camus 1996; Muth 1996; Smith 1998; Hasankhani 2005)
24 with 166 patients showed a significantly higher mean core temperature for the actively
25 warmed group 0.66°C (95% CI 0.50, 0.81) for a control group range of 34.2°C to 35.9°C.
26 There was no significant heterogeneity.
27
28 **Figure 4: Core temperature – intraoperative period; actively warmed IV fluids versus**
29 **room temperature IV fluids; general anaesthesia**

Review: IPH Fluid warming
Comparison: 01 Active fluid warming vs RT fluid warming
Outcome: 09 Core temperature : intraoperative period- A vs RT; Hasankhani SD 0.5

Study or sub-category	N	Active fluid warming Mean (SD)	N	RT fluid Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 CT 15 min							
Hasankhani 2005	30	36.83(0.50)	30	36.51(0.50)		42.94	0.32 [0.07, 0.57]
Smith 1998	18	36.69(0.53)	20	36.41(0.42)		29.30	0.28 [-0.03, 0.59]
Smith 1998b	30	35.90(0.72)	26	35.69(0.47)		27.76	0.21 [-0.10, 0.52]
Subtotal (95% CI)	78		76			100.00	0.28 [0.11, 0.44]
Test for heterogeneity: Chi² = 0.29, df = 2 (P = 0.87), I² = 0%							
Test for overall effect: Z = 3.28 (P = 0.001)							
02 CT 30min							
Camus 1996	9	36.71(0.43)	9	36.50(0.32)		16.44	0.21 [-0.14, 0.56]
Hasankhani 2005	30	36.71(0.50)	30	36.24(0.50)		31.49	0.47 [0.22, 0.72]
Smith 1998	18	36.41(0.40)	20	36.00(0.35)		34.96	0.41 [0.17, 0.65]
Smith 1998b	30	36.01(0.72)	26	35.58(0.59)		17.11	0.43 [0.09, 0.77]
Subtotal (95% CI)	87		85			100.00	0.40 [0.26, 0.54]
Test for heterogeneity: Chi² = 1.46, df = 3 (P = 0.69), I² = 0%							
Test for overall effect: Z = 5.51 (P < 0.00001)							
03 CT 60 min							
Camus 1996	9	36.43(0.43)	9	36.25(0.43)		17.85	0.18 [-0.22, 0.58]
Hasankhani 2005	30	36.40(0.50)	30	35.90(0.50)		44.00	0.50 [0.25, 0.75]
Smith 1998	18	36.31(0.86)	20	35.81(0.63)		12.04	0.50 [0.02, 0.98]
Smith 1998b	30	36.08(0.72)	26	35.82(0.53)		26.11	0.26 [-0.07, 0.59]
Subtotal (95% CI)	87		85			100.00	0.38 [0.21, 0.55]
Test for heterogeneity: Chi² = 2.59, df = 3 (P = 0.46), I² = 0%							
Test for overall effect: Z = 4.44 (P < 0.00001)							
05 CT 2 hours							
Camus 1996	9	36.32(0.64)	9	35.82(0.43)		41.61	0.50 [0.00, 1.00]
Smith 1998b	30	36.48(0.72)	26	35.99(0.88)		58.39	0.49 [0.06, 0.92]
Subtotal (95% CI)	39		35			100.00	0.49 [0.17, 0.82]
Test for heterogeneity: Chi² = 0.00, df = 1 (P = 0.98), I² = 0%							
Test for overall effect: Z = 2.98 (P = 0.003)							
06 CT 3 hours							
Camus 1996	9	36.43(0.54)	9	35.71(0.64)		100.00	0.72 [0.17, 1.27]
Subtotal (95% CI)	9		9			100.00	0.72 [0.17, 1.27]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 2.58 (P = 0.010)							
07 CT 4hours							
Camus 1996	9	36.57(0.96)	9	35.71(0.64)		100.00	0.86 [0.11, 1.61]
Subtotal (95% CI)	9		9			100.00	0.86 [0.11, 1.61]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 2.24 (P = 0.03)							
08 CT Final							
Camus 1996	9	36.70(0.60)	9	35.80(0.60)		8.04	0.90 [0.35, 1.45]
Hasankhani 2005	30	36.40(0.50)	30	35.90(0.50)		38.61	0.50 [0.25, 0.75]
Muth 1996	25	35.10(0.45)	25	34.20(0.70)		23.23	0.90 [0.57, 1.23]
Smith 1998	18	36.20(0.45)	20	35.60(0.45)		30.11	0.60 [0.31, 0.89]
Subtotal (95% CI)	82		84			100.00	0.66 [0.50, 0.81]
Test for heterogeneity: Chi² = 4.50, df = 3 (P = 0.21), I² = 33.3%							
Test for overall effect: Z = 8.17 (P < 0.00001)							

-4   -2   0   2   4
Favours RT fluid   Favours Active fluid

1
2   NB: Scale -4 to 4
3
4   A sensitivity analysis was conducted to examine the assumption that for Hasankhani (2005)
5   the standard deviation for the end of surgery could be used at 15 and 30 minutes; Hasankhani
6   (2005) has been excluded in the forest plot (Figure 4b)
7
8   At 15 minutes, in the remaining two studies (Smith 1998; Smith 1998b) with 99 patients the
9   mean core temperature was significantly higher for the warmed group: MD 0.24°C (95% CI
10   0.03, 0.46) for a control group temperature range 35.6°C to 36.5°C, which is similar to the
11   meta-analysis including Hasankhani 2005 (0.28°C (95% CI 0.11, 0.44).
12
13   At 30 minutes, for a meta-analysis of three studies (Camus 1996; Smith 1998; Smith 1998)
14   with 117 patients the mean difference was significantly higher for the group receiving actively
15   warmed fluids (0.37°C [95% CI 0.20, 0.54]) for a control group range 35.5°C to 36.5°C. This
16   was similar to the meta-analysis that included Hasankhani (WMD 0.40°C [95%CI 0.26, 0.54]).
17
18   At 60 minutes, meta-analysis of three studies (Camus 1996; Smith 1998; Smith 1998b) with
19   117 patients gave a borderline significant difference, favouring fluid warming: WMD 0.29°C
20   (95% CI 0.06, 0.51) for a control group temperature range 35.8°C to 36.2°C. This is fairly
21   similar to the meta-analysis including Hasankhani 2005 (0.38°C [95% CI 0.21, 0.54]).

Figure 4b: Core temperature – intraoperative period; actively warmed IV fluids versus room temperature IV fluids; general anaesthesia; sensitivity analysis
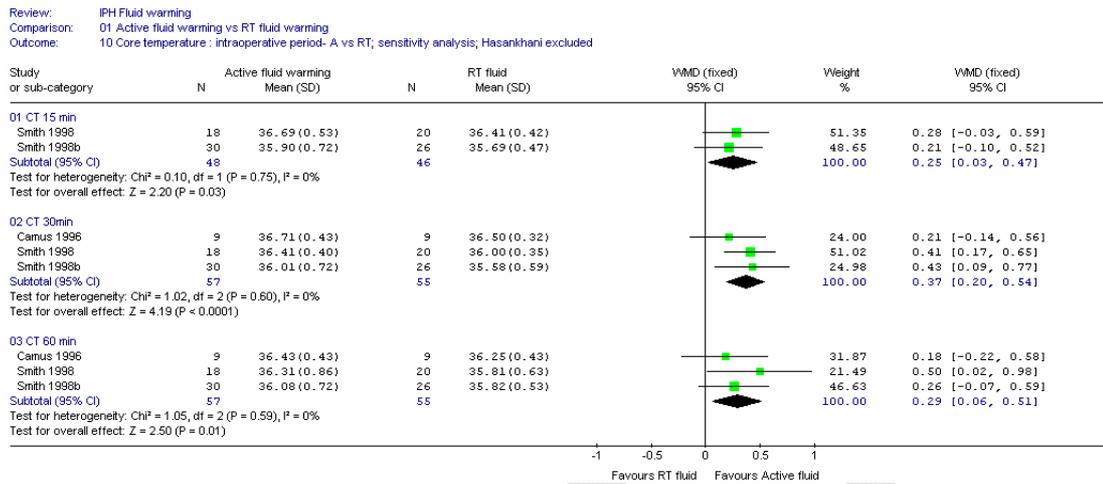
Comparing the mean differences at 15, 30 and 60 minutes in Figure 4a with Figure 4b (sensitivity analysis) it was agreed that excluding Hasankhani (2005) was not justified as the mean difference did not change sufficiently.

4. Number of patients requiring cessation of warming intraoperatively

One study (Smith 1998b) with 56 patients reported the percentage of patients who required cessation of forced air warming in the intraoperative period. There was no significant difference between warmed and unwarmed fluids, but the confidence interval is wide (Figure 5). Cessation of warming was required after 131 minutes (SD 22) and 165 minutes (SD 40) for the intervention (forced air warming and fluids) and the control (forced air warming) groups respectively.

Figure 5: Cessation of warming; actively warmed IV fluids versus room temperature IV fluids; general anaesthesia
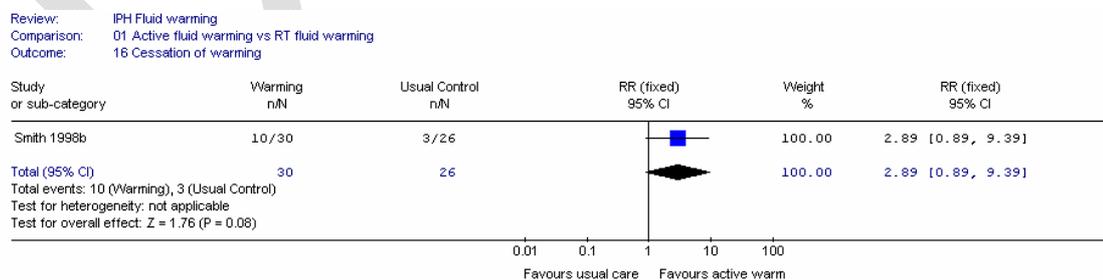
NB: Scale 0.01 to 100

5. Core temperature in PACU

One study (Smith 1998) with 38 patients recorded the core temperature in PACU (on arrival, and at 30 and 60 minutes). Only the results for core temperature at entry into PACU are

1   presented because six patients (2 in the warmed group; 4 in the usual care group) with

2   shivering or core temperature less than 35.5°C were treated with radiant heat during their stay

3   in PACU.

4

5   There was a significantly higher mean core temperature for the active fluid warming group:

6   MD 0.60°C (95% CI 0. 32, 0.88) for a control group temperature of 35.7°C (Figure 6). The

7   confidence interval is fairly wide.

8

9   **Figure 6: Core temperature – PACU; actively warmed IV fluids versus room temperature**

10 **IV fluids; general anaesthesia**

11

12
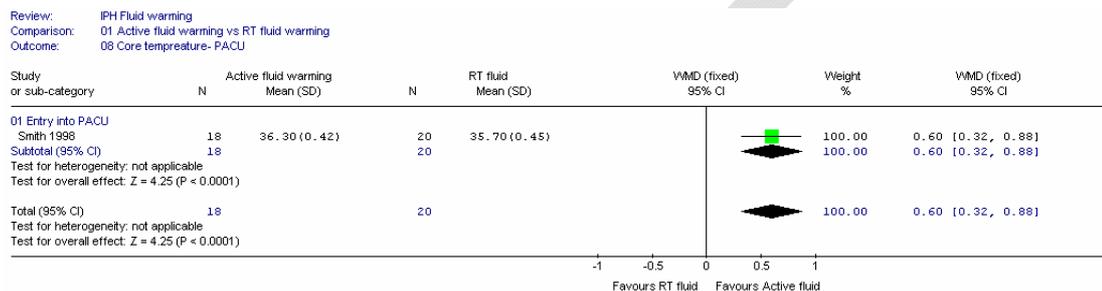
13 **6. Shivering**

14 Five studies reported on shivering (Cooper 1994; Camus 1996; Smith 1998; Smith 1998b

15 Hasankhani 2005). One study (Cooper 1994) did not provide details on how shivering was

16 assessed.

17

18 Methods of assessing shivering varied between the remaining three studies. In one study

19 (Camus 1996) shivering was assessed at 5 minute intervals in recovery by an observer

20 blinded to treatment. Shivering was classified as absent, mild (detected by

21 electrocardiographic artefacts) or severe (clinically obvious). The GDG decided that shivering

22 evaluated with ECG artefacts was not an appropriate method of assessment, because other

23 involuntary movements (e.g. in those with Parkinson's disease) may be recorded. Therefore

24 the incidence of mild shivering was not considered for this study.

25

26 In two studies (Smith 1998; Smith 1998b) shivering was scored as mild if it did not interfere

27 with monitoring and classified as severe if IV meperidine treatment was required. Results were

28 dichotomised to either presence (mild or severe) or absence of shivering. Severity of shivering

29 was assessed on arrival by a PACU nurse blinded to the treatment.

30

31 In one study (Hasankhani 2005) shivering was graded on a 5 point scale (0 = No shivering; 1

32 = Fasciculation of face and lips; 2 = Fasciculation of face and neck; 3 = Visible tremor

33 involving more than one muscle group; 4 = Gross muscular activity involving the entire body).

34 The results were dichotomised to either presence or absence of shivering. Shivering was

1 assessed every 10 minutes after arrival in the recovery room by an assessor blinded to the
2 treatment group.
3
4 Meta-analysis of five studies (Cooper 1994; Camus 1996; Smith 1998; Smith 1998b;
5 Hasankhani 2005) with 186 patients showed the incidence of shivering was significantly lower
6 in the warmed group. The confidence interval is fairly wide (Peto OR 0.33 [95% CI 0.16, 0.68]
7 for a control group range 4% to 70%). This corresponded to an NNT of 6 (95% CI 4, 15).
8 There was no heterogeneity (Figure 7).
9
10 **Figure 7: Shivering; Active IV fluid warming versus room temperature IV fluid; general**
11 **anaesthesia**
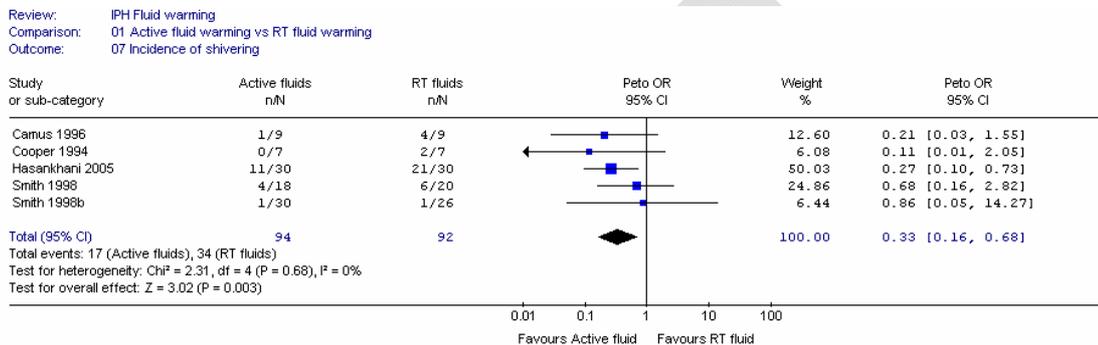
12
13 NB: Scale 0.001 to 100
14
15 **B. Active fluid warming 1 versus active fluid warming 2**
16 **B1. General anaesthesia**
17 Two studies (Patel 1996; Ellis-Stoll 1996) compared two active IV fluid warming mechanisms.
18
19 One study (Patel 1996) with 49 patients undergoing orthopaedic or gynaecological surgery
20 under general anaesthesia compared the effectiveness of countercurrent water heat exchange
21 fluid warmer (group 1) with a dry heat exchange fluid warmer (group 2).
22
23 The groups were not comparable on the following:
24 • Baseline core temperature (0.20°C higher in group 2; p=0.05);
25 • Volume of infused fluids (1.27 litre more in group 1; p=0.03);
26 • Age (mean difference: 11 years higher in group 1; p=0.03).
27
28 This study was not considered for further analysis.
29
30 One study (Ellis-Stoll 1996) with 50 patients compared the effectiveness of continuously
31 warmed IV fluids versus prewarmed IV fluids; patients in both arms received a prewarmed
32 blanket. The study did not report the volume of infused fluids.
33

The study reported the core temperature but not standard deviations or p values. The core temperatures during the intraoperative period for the treatment and control groups were as follows:

- Baseline: 36.8°C versus 36.7°C;
- 30 minutes: 36.1°C versus 36.1°C;
- 60 minutes: 35.9°C versus 35.8°C;
- 120 minutes: 35.4°C versus 35.5°C;
- Final intraoperative (170 minutes): 36.6°C versus 36.8°C;
- Lowest intraoperative (110 versus 120 minutes): 35.6°C versus 35.5°C.

The authors performed an analysis of covariance of mean temperatures and reported that there were no statistically significant differences in the mean intraoperative or postoperative temperatures.

C. Active patient warming plus active fluid warming versus usual care

Five studies (Kurz 1995; Schmied 1996; Zhao 2005; Steinbrook 1997; Motamed 1998) compared the combined effects of active patient and fluid warming in comparison to routine care (unwarmed fluids).

In three studies (Kurz 1995; Schmied 1996; Zhao 2005), patients underwent general anaesthesia. Results for these studies were presented separately from studies in which patients underwent regional anaesthesia (Motamed 1998). In Steinbrook (1997), in addition to randomisation to warming mechanisms, patients were further randomised to receive either combined epidural and general anaesthesia or general anaesthesia. Results for the general anaesthesia group were combined with the other three studies (Kurz 1995; Schmied 1996; Zhao 2005) where appropriate. Results for the combined anaesthesia (epidural-general) patients were presented separately.

Volume of fluids infused for the warmed group and the usual care group, respectively were as follows:

- 3.5 (SD 0.9) versus 3.4 (1.0) litre (Kurz 1995);
- 2.14 (0.65) versus 2.25 (0.74) litre (Zhao 2005);
- 2.5 (0.5) versus 2.9 (0.6) litre (Schmied 1996);
- 3.5 (1.22) versus 2.6 (1.2) litre (Steinbrook 1997; general anaesthesia);
- 4.8 (1.2) versus 4.3 (1.57) litre (Steinbrook 1997; combined anaesthesia);
- 4.4 (0.46) versus 5.2(0.67) litre (Motamed 1998) (volume of fluids infused during surgery and recovery) (combined anaesthesia).

Flow rates were stated in three studies (Kurz 1995; Schmeid 1996; Motamed 1998).

- 10 to 15ml/kg/h (Kurz 1995);

1 • 10ml/kg/h (Schmied 1995);

2 • 6 to 8ml/kg/h (Motamed 1998).

3

4 In one study (Motamed 1998) patients received 0.9% NaCl.

5

6 Results are reported at each of the following time periods: 30, 60, 120, 180 minutes; time
7 when lowest intraoperative temperature was reached; and core temperature at the end of
8 surgery. The incidence of shivering is also reported for two studies (Steinbrook 1997; Zhao
9 2005).

10

11 **C1. General anaesthesia**

12 **1. Core temperature: intraoperative period**

13 Three studies (Kurz 1995; Schmied 1996; Zhao 2005) compared forced air warming plus fluid
14 warming with usual care. In one study (Zhao 2005) blood was warmed as well in the
15 intervention arm (Figure 8), which may have increased the effect size.

16

17 At 60 minutes, meta-analysis of two studies (Kurz 1995; Zhao 2005) with 114 patients showed
18 significantly higher mean core temperatures for the warmed group: WMD 0.41°C (95% CI
19 0.26, 0.57) for a control group temperature 35.6°C. This is clinically significant. There was
20 significant heterogeneity (I^2=62.6%; p=0.02).

21

22 At 2 hours, meta-analysis of two studies (Kurz 1995; Zhao 2005) showed significantly higher
23 mean core temperatures for the warmed group: WMD 1.12°C (95% CI 0.94, 1.30) for a control
24 group temperature range of 34.9°C to 35.47°C. This is clinically significant. There was
25 significant heterogeneity (I^2=80.3%; p=0.02).

26

27 At 3 hours, one study (Kurz 1995) with 74 patients reported core temperature. The mean core
28 temperature was significantly higher for the warmed group at 2.04°C (95% CI 1.85, 2.23) for a
29 control group temperature of 34.5°C.

30

31 The observed heterogeneity at 60 minutes and 2 hours was considered by the proposed
32 factors for subgroup analyses. We also note that the Zhao (2005) study had warmed blood in
33 the intervention group only, but it is unclear when the blood was given.

34

35 In both studies (Kurz 1995; Zhao 2005) patients underwent elective surgery, the mean age of
36 the patients was less than 60 years, and duration of surgery was over 3 hours. Information on
37 BMI status was not available in either study. The studies differed on ASA status, with Kurz
38 (1995) including I-III status patients. There were 4/74 patients with ASA III status.

39

In terms of factors specific to warming devices (setting and site of warming), in each study the setting on the forced air warming was 'high'. The setting was approximately 40°C in one study (Kurz 1995). In one study (Zhao 2005) setting was at high level (42 to 43°C) and switched to medium (41 to 42°C) if core temperature was above 37.8°C. We note that the mean core temperature was below 36.0°C throughout the entire intraoperative period for the control groups in both studies, but dropped to 34.5°C at 3 hours in the Kurz (1995) study.

In Kurz (1995) the site of forced air warming was restricted to the upper body and the lower body in Zhao (2005).

It was thus difficult to account for the observed heterogeneity, but we note that the two studies are each statistically significant, with higher mean temperatures for the warmed groups.

2. Core temperature: end of surgery

Core temperature at the end of surgery was reported in three studies (Kurz 1995; Schmied 1996; Zhao 2005) with 174 patients. Duration of surgery was less than 3 hours in one study (Schmied 1996) and over 3 hours in two other studies (Kurz 1995; Zhao 2005). Meta-analysis of the three studies showed significant heterogeneity (I^2=98.1%; $p<0.00001$). Each study was statistically significant (Figure 8).

3. Lowest intraoperative core temperature

The lowest intraoperative temperature was reported in two studies (Kurz 1995; Zhao 2005) with 114 patients. In Kurz (1995), the lowest temperature was recorded at 1 hour and 3 hours for the treatment and control groups respectively. In Zhao (2005), the lowest temperature was recorded at 40 minutes and 2.6 hours for the treatment and control groups respectively.

Meta-analysis of the two studies showed a statistically significant mean difference: WMD 1.18°C (95% CI 1.02, 1.34) for a control group temperature of 34.5 to 35.2°C. There was significant heterogeneity (I^2=72.5%; $p<0.06$).

Figure 8: Core temperature: intraoperative period; active patient warming 1 + active fluid warming versus usual care; general anaesthesia
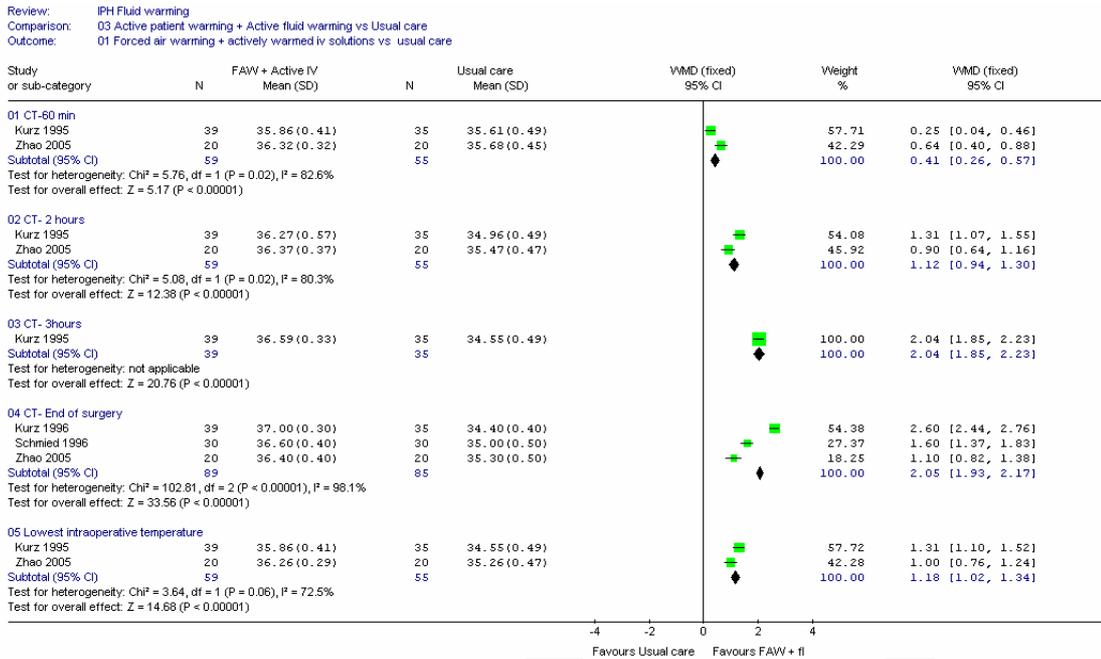
NB: Scale -4 to 4

Intraoperative complications

4. Blood loss: intraoperative period

Two studies (Schmied 1996; Zhao 2005) reported intraoperative blood loss. Meta-analysis of the two studies showed significant heterogeneity (I^2= 90.2%, p= 0.001). Each study was statistically significant, but in different directions. The volume of blood loss (0.22 litre) was significantly higher in the actively warmed group in Zhao (2005) in 40 patients undergoing abdominal surgery. Schmeid (2005) with 60 patients undergoing total hip arthroplasty showed a significantly higher volume of blood loss (0.23 litre) for the unwarmed group (Figure 9). The result for the Zhao (2005) study was unexpected.

Figure 9: Blood Loss: Active patient warming 1 + active fluid warming versus usual care; general anaesthesia
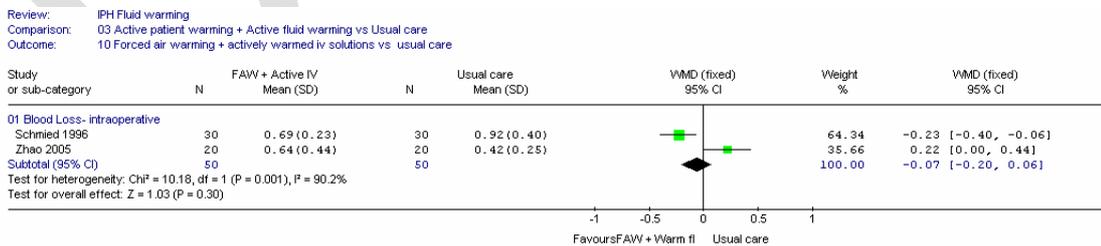
Postoperative outcomes

5. Core temperature: PACU

Three studies (Kurz 1995; Schmied 1996; Steinbrook 1997) reported core temperature in PACU. Core temperature in PACU was recorded on arrival, up to 6 hours (Kurz 1995) and 24 hours postoperatively (Schmied 1996). In one study (Steinbrook 1997) it was unclear if the

1   core temperature reported for the postoperative period was recorded immediately on arrival or
2   prior to discharge. In Kurz (1995), it was stated that neither group was warmed during the
3   recovery period (Figure 10).
4
5   Meta-analysis of two studies (Kurz 1995; Steinbrook 1997) with 89 patients showed a
6   significantly higher mean core temperature at entry into PACU for the actively warmed group:
7   WMD 2.07°C (95% CI 1.87, 2.28) for a control group temperature range 34.7°C to 35.0°C.
8   There was no significant heterogeneity.
9
10 After 1 hour in PACU, one study (Kurz 1995) with 74 patients showed a significantly higher
11 mean core temperature for the warmed group: MD 1.72°C (95% CI 1.47, 1.97) for a control
12 group temperature of 35.2°C. The difference is clinically significant.
13
14 After 2 hours in PACU, meta-analysis of two studies (Kurz 1995; Schmeid 2005) with 134
15 studies showed a significantly higher mean core temperature for the warmed group: MD
16 1.17°C (95% CI 0.99, 1.35) for a control group temperature of 35.7°C to 35.9°C. The
17 difference is clinically significant. The confidence interval is fairly wide. There was significant
18 heterogeneity (I^2= 77.0%; p=0.04).
19
20 After 3 hours in PACU, one study (Kurz 1995) with 74 patients showed a significantly higher
21 mean core temperature for the warmed group: MD 0.98°C (95% CI 0.75, 1.21) for a control
22 group temperature of 36.3°C. The difference is clinically significant.
23
24   After 4 hours in PACU, one study (Kurz 1995) with 74 patients showed a significantly higher
25 mean core temperature for the warmed group: MD 0.65°C (95% CI 0.44, 0.86) at a control
26 group temperature of 36.7°C.
27
28 After 5 hours in PACU, one study (Kurz 1995) with 74 patients showed a significantly higher
29 mean core temperature for the warmed group: MD 0.49°C (95%CI 0.32, 0.66) for a control
30 group temperature of 37.0°C. The difference is clinically significant.
31
32 After 6 hours in PACU, the mean difference was not significant.
33
34 **Figure 10: Core temperature: PACU: active patient warming 1 + active fluid warming**
35 **versus usual care; general anaesthesia**
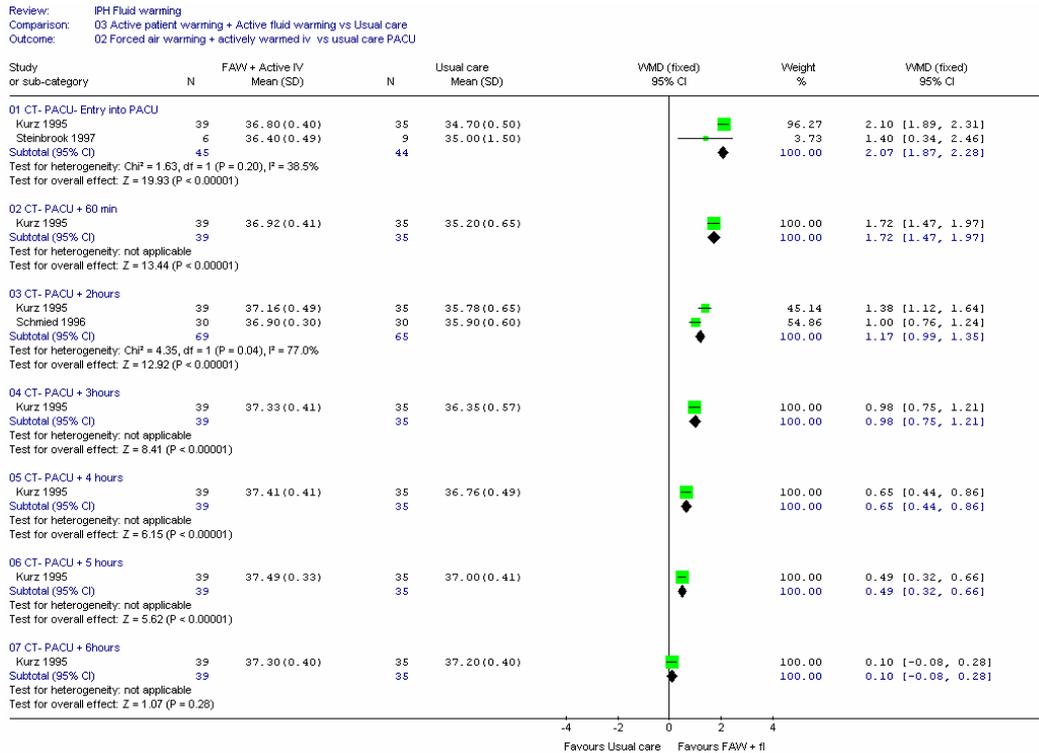
NB: Scale -4 to 4

6. Blood Loss (PACU)

One study (Schmied 1996) with 30 patients reported cumulative blood loss (ml) from 3 hours after surgery until 24 hour postoperative period. The volume of cumulative blood loss (480ml) was significantly higher for the unwarmed group for the entire postoperative period (Figure 11).

Figure 11: Blood loss (PACU): active patient warming 1 + active fluid warming versus usual care; general anaesthesia
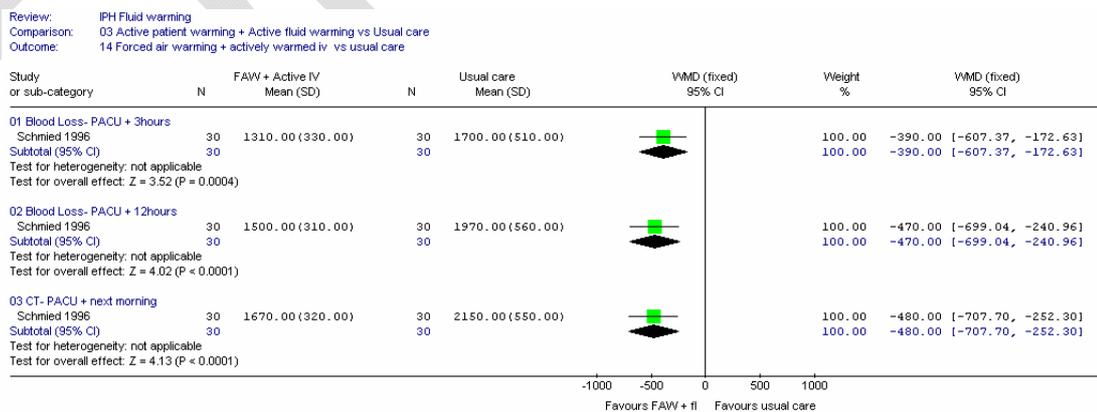
NB: Scale -1000 to 1000

7. Extubation time

One study (Zhao 2005) with 40 patients showed the actively warmed group had a significantly shorter extubation time (by 8.7 minutes) compared to the usual care group (Figure 12).

1

2 **Figure 12: Extubation time: active patient warming 1 + active fluid warming versus**

3 **usual care; general anaesthesia**

Review: IPH (Version 01)
Comparison: 12 Active patient warming + Active fluid warming vs nothing/usual care - General anaesthesia
Outcome: 07 Extubation time

Study or sub-category	N	FAW + Fluid Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Zhao 2005	20	17.70(5.80)	20	26.40(10.00)		100.00	-8.70 [-13.77, -3.63]
Total (95% CI)	20		20			100.00	-8.70 [-13.77, -3.63]

Test for heterogeneity: not applicable
Test for overall effect: Z = 3.37 (P = 0.0008)

-100   -50   0   50   100
Favours usual care   Favours FAW + Fluid

4

5 NB: Scale -100 to 100

6
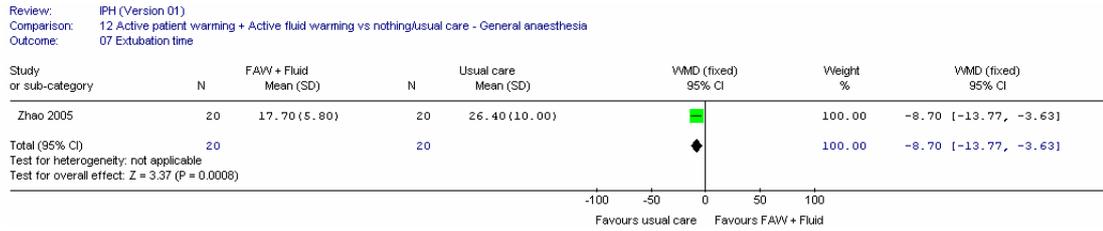
7 **8. Shivering**

8 Three studies (Kurz 1995; Steinbrook 1997; Zhao 2005) assessed shivering. Two studies

9 (Kurz 1995; Zhao 2005) reported on the method by which shivering was assessed and varied

10 between the studies.

11

12 In one study (Kurz 1995) shivering was evaluated on a three-point scale: with grade 0

13 indicated no shivering; grade 1 indicating mild or intermittent shivering; grade 2 indicated

14 moderate shivering; and grade 3 indicating prolonged, intense shivering. The paper reported

15 the percentage of patients demonstrating shivering grade 2 or grade 3. In one study (Zhao

16 2005) shivering was evaluated by a blinded observer and classified as absent, mild, medium,

17 or severe. Total incidence of shivering was reported for the treatment and control groups.

18

19 Meta-analysis of three studies (Kurz 1995; Steinbrook 1997; Zhao 2005) with 129 patients

20 showed a significantly lower incidence of shivering in the actively warmed group (Peto OR

21 0.12 [95% CI 0.05, 0.24]). This corresponded to an NNT 3 (95% CI 2, 4) for a control group

22 rate range of 30% to 74% (Figure 13). There was no heterogeneity.

23

24 **Figure 13: Incidence of shivering: active patient warming 1 + active fluid warming**

25 **versus usual care; general anaesthesia**

Review: IPH Fluid warming
Comparison: 03 Active patient warming + Active fluid warming vs Usual care
Outcome: 06 Incidence of shivering

Study or sub-category	FAW + Active fl n/N	usual care n/N	Peto OR 95% CI	Weight %	Peto OR 95% CI
Kurz 1995	7/39	26/35		67.41	0.11 [0.04, 0.26]
Steinbrook 1997	1/6	5/9		13.51	0.22 [0.03, 1.69]
Zhao 2005	0/20	6/20		19.08	0.10 [0.02, 0.56]
Total (95% CI)	65	64		100.00	0.12 [0.05, 0.24]

Total events: 8 (FAW + Active fl), 37 (usual care)
Test for heterogeneity: Chi² = 0.45, df = 2 (P = 0.80), I² = 0%
Test for overall effect: Z = 5.65 (P < 0.00001)

0.01   0.1   1   10   100
Favours Active warm   Favours usual care

26

27 NB: Scale 0.01 to 100

28
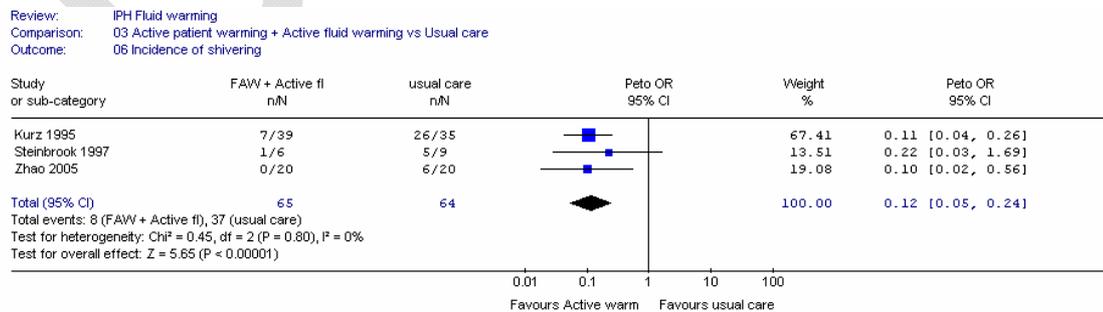
29 **9. Thermal comfort**

1 One study (Kurz 1995) with 74 patients reported thermal comfort in the postoperative period.
2 Thermal comfort was evaluated using a visual analogue scale (VAS) on a 10mm scale, with
3 0mm indicating intense cold, 50mm indicating thermal comfort and 100mm indicating intense
4 warmth (Figure 14).
5
6 At entry into PACU, thermal comfort was significantly higher for the actively warmed group:
7 MD 34.87mm (95% CI 28.55, 41.19) for a control group thermal comfort 18.46mm.
8
9 After 1 hour in PACU, the difference in thermal comfort was significantly higher for the actively
10 warmed group: MD 30.77mm (95% CI 23.28, 38.26) for a control group thermal comfort
11 26.67mm.
12
13 After 2 hours in PACU, the difference in thermal comfort remained significantly higher for the
14 actively warmed group: MD 12.31mm (95% CI 7.63, 16.99) for a control group thermal comfort
15 45.13mm.
16
17 After 3 hours in PACU, the difference in thermal comfort was not significant.
18

19 **Figure 14: Thermal comfort; active patient warming 1 + active fluid warming versus**
20 **usual care; general anaesthesia**

21
22 NB: Scale -100 to 100
23
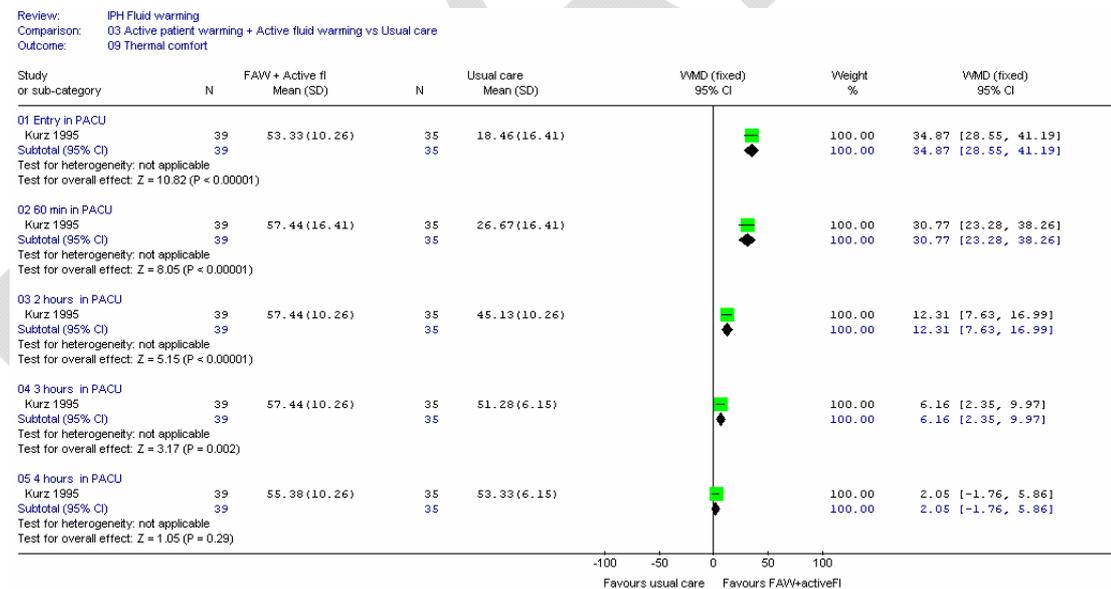
24 **10. Pain**
25 One study (Kurz 1996) assessed post-surgical pain by an observer blinded to the patients'
26 group assignment and temperature, using a VAS scale, with 0mm indicating no pain and
27 100mm indicating the most intense pain imaginable.
28

1   The paper did not report means and standard deviations and only reported a narrative

2   synopsis of pain scores.

3

4   The authors reported that VAS pain scores were 'virtually identical' in both groups at each

5   postoperative measurement interval. Pain score was near 50mm after surgery, approximately

6   30mm after 1 hour and approximately 10mm after 2 hours.

7

8   **Combined epidural-general anaesthesia**

9   Two studies (Steinbrook 1997 subgroup; Motamed 1998) undergoing surgery under mixed

10   anaesthesia (epidural-general) compared active warming (forced air and fluid warming) with

11   routine thermal care. One study (Motamed 1998) reported the core temperature at the end of

12   surgery, and one study (Steinbrook 1997) reported core temperature in the PACU and

13   incidence of shivering.

14

15   **1. Core temperature: End of surgery**

16   One study (Motamed 1998) with 30 patients undergoing colorectal surgery under epidural

17   anaesthesia compared active warming (combination of convective warming with fluid and

18   blood warming) with usual care and reported the core temperature at the end of surgery.

19

20   At the end of surgery, the mean core temperature was significantly higher for the warmed

21   group: MD 1.40°C (95% CI 1.02, 1.78), but the confidence interval is fairly wide (Figure 15).

22

23   **Figure 15 Core temperature: end of surgery; active patient warming 1 + active fluid**

24   **warming versus usual care; combined epidural-anaesthesia anaesthesia**

Review: IPH Fluid warming
Comparison: 04 FAW + Actively warmed iv fluids vs room temperature iv fluids
Outcome: 01 Core temperature- end of surgery

Study or sub-category	MD (SE)	MD (fixed) 95% CI	Weight %	MD (fixed) 95% CI
Motamed 1998	1.4000 (0.1940)		100.00	1.40 [1.02, 1.78]
Total (95% CI)			100.00	1.40 [1.02, 1.78]

Test for heterogeneity: not applicable
Test for overall effect: Z = 7.22 (P < 0.00001)

-4 -2 0 2 4
Favours usual care   Favours active warm

25

26   NB: Scale -4 to 4

27

28   **Postoperative Outcomes**

29   **2. Core temperature: PACU**

30   One study (Steinbrook 1997) with 9 patients reported core temperature in PACU. It was

31   unclear if measurement was taken immediately on arrival in the PACU or just prior to

32   discharge. The mean core temperature was significantly higher for the warmed group: MD

33   1.30°C (95% CI 0.42, 2.18) for a control group temperature of 35.1°C. The difference is

34   clinically significant. The confidence interval is wide (Figure 16).

35

Figure 16: Core temperature: PACU; active patient warming 1 + active fluid warming versus usual care; combined epidural-general anaesthesia



```
Review:      IPH Fluid warming
Comparison:  03 Active patient warming + Active fluid warming vs Usual care
Outcome:     03 Forced air warming + actively warmed iv (37oC) vs usual care; Epidural-general
```

Study or sub-category	N	FAW + Active IV Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
03 CT- PACU							
Steinbrook 1997	5	36.40(0.45)	4	35.10(0.80)		100.00	1.30 [0.42, 2.18]
Subtotal (95% CI)	5		4			100.00	1.30 [0.42, 2.18]

Test for heterogeneity: not applicable
Test for overall effect: Z = 2.90 (P = 0.004)

Favours Usual care   Favours FAW + fl
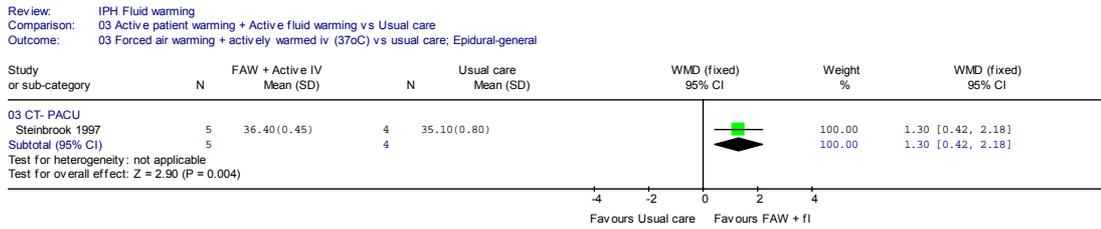
NB: Scale -4 to 4

3. Shivering

One study (Steinbrook 1997) with 9 patients assessed shivering in PACU. Details on how shivering was assessed was not provided (Figure 17).

Figure 17: Shivering; active patient warming 1 + active fluid warming versus usual care; combined epidural-general anaesthesia


```
Review:      IPH Fluid warming
Comparison:  03 Active patient warming + Active fluid warming vs Usual care
Outcome:     07 Incidence of shivering; epidural-regional
```

Study or sub-category	FAW + Active fl n/N	usual care n/N	RR (fixed) 95% CI	Weight %	RR (fixed) 95% CI
Steinbrook 1997	2/5	3/4		100.00	0.53 [0.16, 1.79]
Total (95% CI)	5	4		100.00	0.53 [0.16, 1.79]

Total events: 2 (FAW + Active fl), 3 (usual care)
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.02 (P = 0.31)

Favours Active warm   Favours usual care
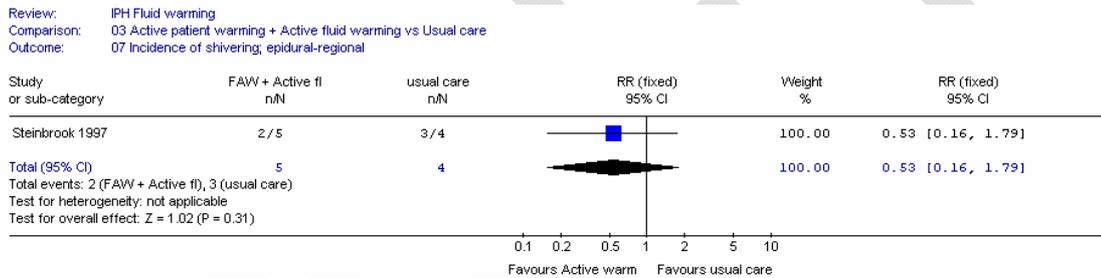
II. Irrigation fluid warming

A. Fluid warming versus no warming (room temperature fluids)

Six studies (Dyer 1986; Jaffe 2001; Moore 1996; Pit 1996; Monga 1996; Kelly 2000) compared the effectiveness of warmed irrigation fluid with room temperature fluids. One study gave the patients general anaesthesia (Moore 1996); in three studies (Dyer 1986; Pit 1996; Kelly 2000) patients received regional anaesthesia and in one study (Monga 1996) the majority of the patients (n=21/26) received spinal anaesthesia and will be combined with the above studies where appropriate. One study did not state the type of anaesthesia (Jaffe 2001) so this study was included with the general anaesthesia study. We note that two studies (Moore 1996; Jaffe 2001) had additional active warming of the patients in both groups.

A1. Regional anaesthesia

In one study (Pit 1996) irrigation fluid (5% sorbitol containing chlorhexidine [1:5000]) was warmed by a heater set at 37.5°C, warmed glycine 1.5% bladder irrigation solution was prewarmed to 37°C in one study (Dyer 1986) and prewarmed saline at 40°C in the other study (Kelly 2000). Patients received active or passively warmed 1.5% glycine in one study (Monga 1986). The GDG advised that although the type of warming varied (active in Pit 1996 and

1   passive in Dyer 1986 and Kelly 2000) it was acceptable to pool results because of the rapid
2   delivery of irrigation fluids.
3
4   The volume of irrigation fluids for the treatment and control groups were as follows:
5   •   11.8 litres (SD 11.0) and 11.7 litres (SD 10.7) (Kelly 2000);
6   •   8.4 litres (SD 4.4) and 8.4 litres (SD 4) (Dyer 1986).
7
8   Pit (1996) stated that patients received 5% sorbitol containing chlorhexidine (1:5000) in 5 litre
9   bags. Monga (1996) did not report the volume of fluids infused intraoperatively.
10
11   In one study (Kelly 2000) the baseline core temperature in the control group was 0.30°C
12   higher, and this significant difference was compared with the effect size.
13
14   We note that one study (Monga 1996) did not provide details on how many patients were
15   randomised to each group. We assumed an equal randomisation.
16
17   **1. Mean percent change in core temperature intraoperatively**
18   One study (Kelly 2000) reported mean percent change in core temperature from baseline at
19   various times in the intraoperative period. The largest mean difference was 0.34% at 90
20   minutes. Baseline core temperatures were 36.1°C or 36.4°C, so a difference of 0.34% is about
21   0.12°C, i.e., less than the difference in baseline. Therefore this study was considered to be
22   confounded.
23
24   **2. Change in core temperature**
25   Three studies reported change in core temperature. One study (Dyer 1986) with 47 patients
26   reported change in core temperature from the start of resection. The duration of resection was
27   not significantly different in the two groups. The mean difference in core temperature was not
28   significant at 30, 60 and 120 minutes (Figure 18).
29
30   One study (Pit 1996) with 56 patients reported the difference between the lowest rectal
31   temperature and the initial core temperature. The authors reported that the lowest
32   intraoperative temperature was reached after the resection was completed (28 versus 29
33   minutes for the treatment and control groups respectively). However, it is unclear how much
34   time had elapsed since the completion of the resection.
35
36   The change in the mean core temperature was significantly less for the actively warmed
37   irrigation fluid group: MD 0.97°C (95%CI 0.51, 1.43) for a change in control group temperature
38   of -1.7°C. The confidence interval is fairly wide. We note that the initial rectal temperature was
39   36.3°C (SD 0.5) and 36.3°C (SD 0.4) for the treatment and control groups respectively (Figure
40   18).

1

2 One study (Monga 1986) with 28 patients undergoing transurethral resection of the prostate

3 reported change in core temperature (difference between pre and postoperative periods). The

4 confidence interval is too wide to determine if there is a difference in core temperature.

5

6 **Figure 18: Change in intraoperative core temperature; irrigation fluid warming versus**

7 **room temperature fluids; regional anaesthesia**

8

9 NB: Scale -4 to 4

10
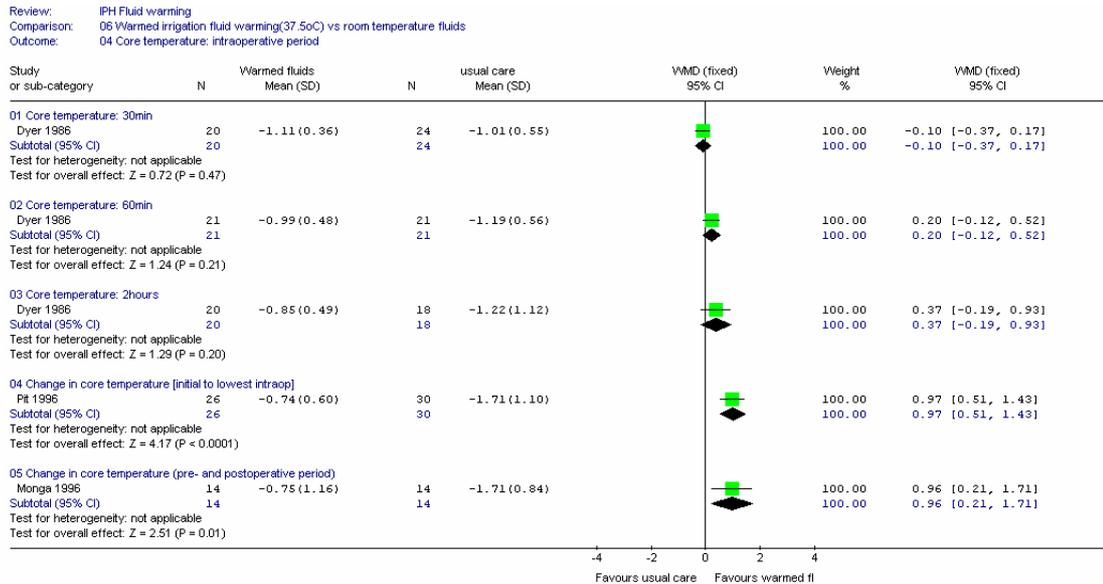
11 **Postoperative period**

12 **3. Thermal discomfort**

13 One study (Pit 1996) reported thermal discomfort (perception of cold) for 58 patients. Patients

14 in the active irrigation group reported feeling cold significantly less than the control group [RR

15 $0.29°C$ (95% 0.11, 0.76)]. This corresponded to an NNT of 3 (95% CI 2, 8) for a control group

16 rate of 50% (Figure 19). The confidence interval is wide.

17

18 **Figure 19: Thermal comfort; irrigation fluid warming versus room temperature fluids;**

19 **regional anaesthesia**

20

21

22 **A2. General and unstated anaesthesia**

i. Warmed irrigation fluid (33.1°C) versus room temperature irrigation fluid (warmed blanket in both groups) (Jaffe 2001)

ii. Warmed irrigation fluid (39°C) versus ambient temperature irrigation fluid (20–22°C) + heating blanket in both groups (Moore 1996)

Two studies (Moore 1996; Jaffe 2001) compared the effectiveness of warmed irrigation fluid with room temperature fluid; in each study patients in both arms received active patient warming.

In Moore (1996) the type of irrigation fluid was lactated Ringer's solution and in the other (Jaffe 2001) patients received glycine. In one study (Moore 1996), patients in both groups rested on a heating blanket (37.8°C) and in the other study (Jaffe 2001), patients in both groups received a warmed blanket (approximately 45°C).

The volume of irrigation fluid for the warmed and room temperature groups was as follows:

- 1.26 litre (SD 0.83) versus 1.48 litre (SD 0.92) (Moore 1996);
- 17.60 litre (SD 10.13) and 17.33 litre (SD 12.23) (Jaffe 2001).

In one study (Moore 1996) the baseline core temperature was not stated and in the other (Jaffe 2001) the baseline core temperature was above 36.0°C for both groups and there was no significant difference.

1. Incidence of hypothermia

One study (Moore 1996) with 29 patients reported the incidence of hypothermia (core temperature less than 36°C; time of measurement not stated). There was no significant difference in the incidence of hypothermia (Figure 20).

Figure 20: Incidence of hypothermia: irrigation fluid warming versus room temperature fluids
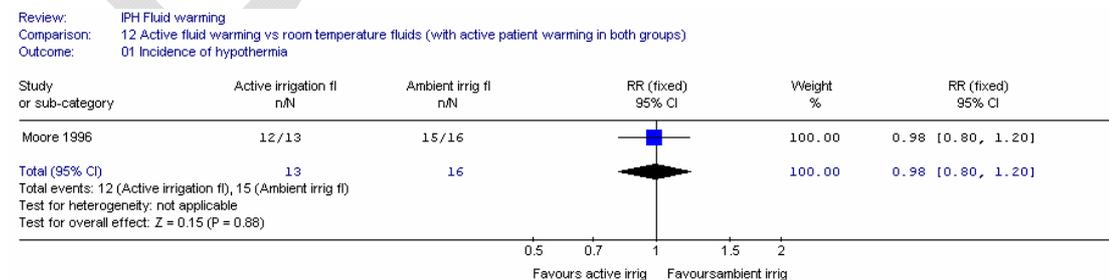
NB: Scale 0.5 to 2

2. Core temperature

1　One study (Moore 1996) reported intraoperative core temperatures, and the end of surgery

2　core temperature was reported for two studies (Moore 1996; Jaffe 2001), which were

3　combined in a meta-analysis. Mean duration of surgery was approximately 100 minutes in

4　Jaffe (2001), and the final intraoperative temperature was recorded at 150 minutes in Moore

5　(1996). The Moore (1996) study recorded both tympanic membrane and oesophageal

6　temperatures and results for both are given below (Figures 21 and 21b).

7

8　The mean difference was not significant at 30 and 60 minutes. At longer times there was

9　significant drop out of patients; the total number had dropped down to 12 patients (of 29) at 2

10　hours and 8 patients at 135 minutes. Therefore, the results at these durations were excluded

11　from the analysis.

12

13　**3. End of surgery**

14　Two studies reported core temperature at end of surgery (Moore 1997; Jaffe 2001). Results

15　from one study (Moore 1997) were excluded from the analysis as there was a significant drop

16　out of patients. At the end of surgery one study (Jaffe 2001) with 56 patients showed no

17　significant difference in oesophageal core temperature: MD 0.05 (95%CI -0.14, 0.24) (Figure

18　21) and no significant difference in tympanic core temperature, although the confidence

19　intervals are wide (Figure 21b).

20

21　**Figure 21: Core temperature (oesophageal): irrigation fluid warming versus room**

22　**temperature fluids**

Review:　　　IPH Fluid warming
Comparison:　12 Active fluid warming vs room temperature fluids (with active patient warming in both groups)
Outcome:　　02 Active fluid warming vs room temperature fluids (with active patient warming in both groups)

Study or sub-category	N	Active irrig Mean (SD)	N	Ambient irrig Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 Core temperature- 30 min							
Moore 1996	13	-0.62(0.82)	16	-0.94(0.65)		100.00	0.32 [-0.23, 0.87]
Subtotal (95% CI)	13		16			100.00	0.32 [-0.23, 0.87]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 1.14 (P = 0.25)							
02 Core temperature- 60 min							
Moore 1996	13	-0.78(0.94)	16	-1.23(0.52)		100.00	0.45 [-0.12, 1.02]
Subtotal (95% CI)	13		16			100.00	0.45 [-0.12, 1.02]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 1.54 (P = 0.12)							
05 Core temperature- End of surgery/final intraop							
Jaffe 2001	29	36.83(0.28)	27	36.78(0.44)		100.00	0.05 [-0.14, 0.24]
Subtotal (95% CI)	29		27			100.00	0.05 [-0.14, 0.24]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 0.50 (P = 0.61)							

-4　-2　0　2　4
Favours active irrig　Favours ambient irri

24　NB: Scale -4 to 4

25

26　**Figure 21b: Core temperature (tympanic): irrigation fluid warming versus room**

27　**temperature fluids**

Review: IPH Fluid warming
Comparison: 12 Active fluid warming vs room temperature fluids (with active patient warming in both groups)
Outcome: 03 Active fluid warming vs room temperature fluids (with active patient warming in both groups); TYMPANIC
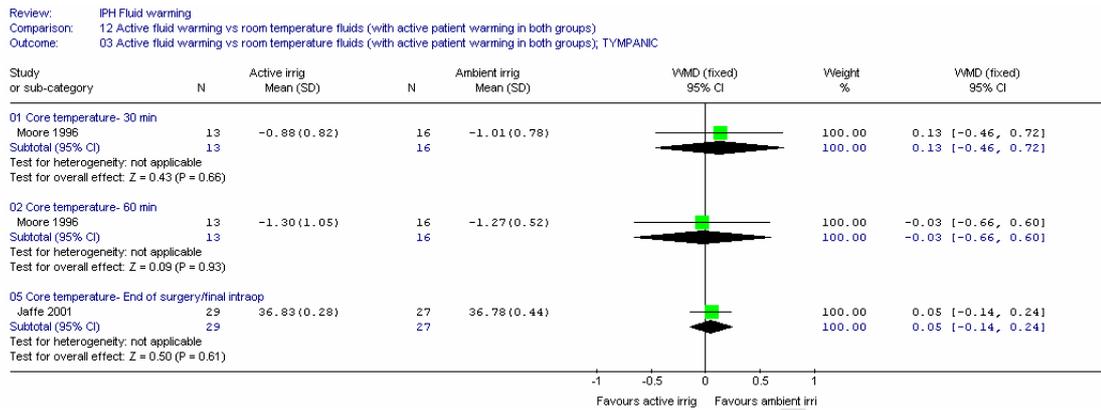
IV. Other comparisons

A. Thermal insulation plus active fluid warming versus usual care

A1. Regional anaesthesia

One study (Dyer 1986) with 48 patients undergoing transurethral resection of the prostate under spinal anaesthesia compared the effectiveness of reflective blankets combined with warmed irrigation fluid versus usual care. The warmed glycine 1.5% bladder irrigation solution was prewarmed to 37°C.

1. Core temperature

At 30 minutes the change in mean core temperature was significantly less for the warmed group: MD 0.31°C (95% CI 0.01, 0.61) for a change in control group temperature of -1.01°C. The confidence interval is fairly wide.

At 60 minutes the change in mean core temperature was significantly less for the warmed group: MD 0.37°C (95% CI 0.03, 0.71) for a change in control group temperature of -1.19°C. The confidence interval is fairly wide.

At 2 hours the change in mean core temperature was significantly less for the warmed group: MD 0.73°C (95% CI 0.13, 1.33) for a change in control group temperature of -1.22°C. The confidence interval is wide.

Figure 22: Core temperature: intraoperative period; thermal insulation + active fluid warming versus usual care; regional anaesthesia

```
Review:        IPH Fluid warming
Comparison:    13 Thermal insl + fluids vs usual care
Outcome:       01 Intraoperative core temperature [after resection]

Study                    Thermal + fl            usual care          WMD (fixed)      Weight      WMD (fixed)
or sub-category      N    Mean (SD)       N      Mean (SD)             95% CI            %           95% CI

01 Core temperature:30 min
   Dyer 1986         22   -0.70(0.50)     24    -1.01(0.55)                          100.00    0.31 [0.01, 0.61]
Subtotal (95% CI)    22                   24                                         100.00    0.31 [0.01, 0.61]
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.00 (P = 0.05)

02 Core temperature:60 min
   Dyer 1986         22   -0.82(0.58)     21    -1.19(0.56)                          100.00    0.37 [0.03, 0.71]
Subtotal (95% CI)    22                   21                                         100.00    0.37 [0.03, 0.71]
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.13 (P = 0.03)

03 Core temperature:2 hours
   Dyer 1986         22   -0.49(0.72)     18    -1.22(1.12)                          100.00    0.73 [0.13, 1.33]
Subtotal (95% CI)    22                   18                                         100.00    0.73 [0.13, 1.33]
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.39 (P = 0.02)

                                                    -4    -2     0     2     4
                                               Favours usual care   Favours TI+warmed fl
```

NB: Scale -4 to 4

B. Thermal insulation + active fluid warming versus active patient warming

B1. General anaesthesia

One study (Patel 1997) with 37 patients undergoing gynaecological, orthopaedic and general surgery under general anaesthesia compared the effectiveness of combined active fluid warming and thermal insulation versus forced air warming. Thermal insulation was applied in the holding area, and it is unclear the duration of time between application and induction of anaesthesia. Patients in this group continued to receive thermal insulation in the intraoperative phase and in the postoperative period. There was no significant difference in the volume of infused fluids; 2.3 litres (SD 1.3) and 2.6 litres (SD 1.2) for the treatment and control groups respectively. We note the baseline core temperature for both groups was above 36.0°C. The difference in baseline core temperature was significantly higher for the group assigned to forced air warming (0.30°C). Results were considered only where the baseline difference is less than 20% of the effect size.

1. Incidence of hypothermia

One study (Patel 1997) with 35 patients reported the number of patients with a core temperature less than or equal to 35.9°C at the end of surgery. Duration of surgery was over 2.5 hours. The confidence interval is too wide to determine significance (Figure 23).

Figure 23: Incidence of hypothermia: thermal insulation + active fluid warming versus active patient warming; general anaesthesia


```
Review:        IPH Fluid warming
Comparison:    08 FAW vs Thermal insl + Active fluid warming
Outcome:       03 Incidence of hypothermia

Study                 Active fl + thermal    FAW           RR (fixed)        Weight      RR (fixed)
or sub-category            n/N               n/N            95% CI             %          95% CI

Patel 1995               5/16               1/19                            100.00    5.94 [0.77, 45.73]

Total (95% CI)           16                 19                             100.00    5.94 [0.77, 45.73]
Total events: 5 (Active fl + thermal), 1 (FAW)
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.71 (P = 0.09)

                                         0.01   0.1    1    10    100
                                      Favours Active fl+TI   Favours FAW
```
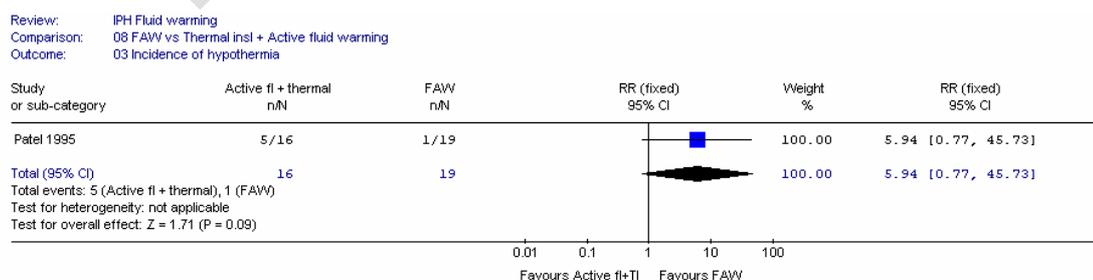
NB: Scale 0.01 to 100

1   **2. Core temperature – intraoperative period**

2   One study (Patel 1997) reported the core temperature during the intraoperative period. The

3   mean difference was not significant throughout the intraoperative period, although the

4   confidence intervals are fairly wide (Figure 24).

5

6   **3. Lowest intraoperative core temperature**

7   Lowest intraoperative was recorded at 1 hour and at 2 hours 45 minutes for the thermal

8   insulation and the active warming groups respectively. The mean difference was not

9   significant (Figure 24).

10

11 **Figure 24: Core temperature: intraoperative period; thermal insulation + active fluid**

12 **warming versus active patient warming; general anaesthesia**

13

14 NB: Scale -4 to 4

15
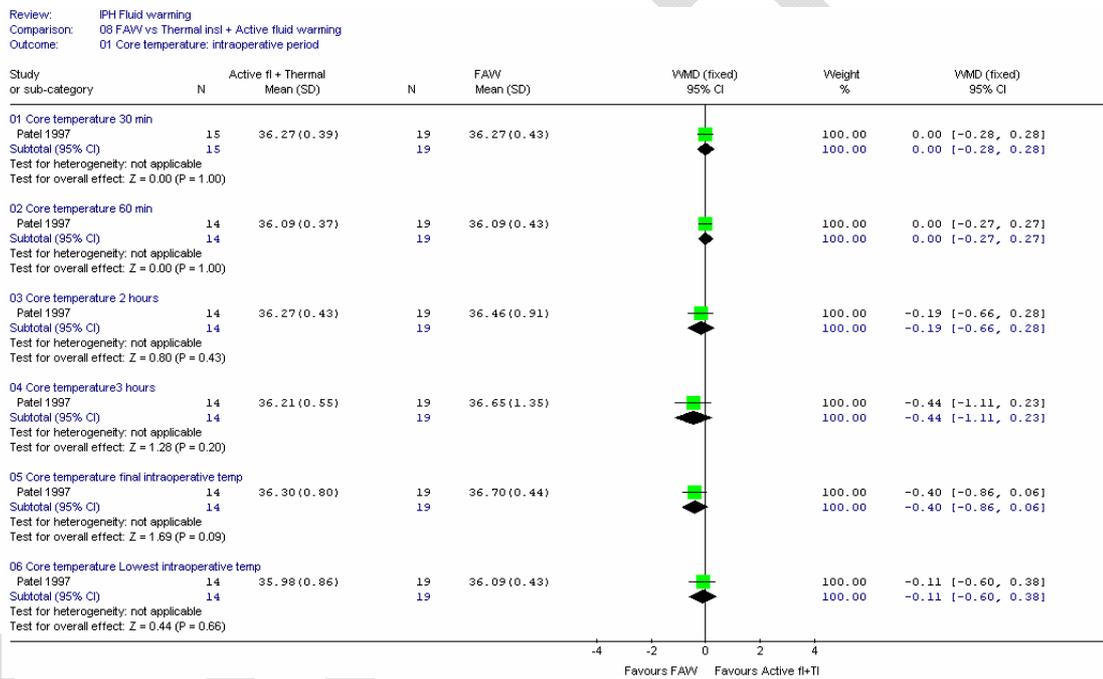
1 **10.6 Gases (Inspired and Insufflation)**

2 **Characteristics of clinical studies included in the review (Appendix C)**

3 Twenty- three studies [26 comparisons] are included in this review (Bäcklund 1998; Conahan

4 1987; Champion 2006; Eckerbom 1990; Farley 2004; Goldberg 1992 [2 comparisons]; Hamza

5 2005; Hynson 1992; Joachimsson 1987; Johansson 2003 [3 comparisons]; Mouton 1999;

6 Nelskylä 1999; Nguyen 2002; Ott 1998; Saad 2000; Savel 2005; Slim 1999; Stone 1981;

7 Tølløfsrud 1984a; Tølløfsrud 1984b; Ouellette 1993; Wills 2001; Youngberg 1985). Reasons

8 for exclusion are listed in Appendix E.

9

10 A total of 948 patients were included in the review. Fourteen studies had fewer than 20

11 patients in each arm (Stone 1981; Tølløfsrud 1984a; Tølløfsrud 1984b; Conahan 1987;

12 Ouellette 1993; Bäcklund 1998; Eckerbom 1990; Goldberg 1992 [2 comparisons]; Hynson

13 1992; Nelskylä 1999; Saad 2000; Nguyen 2002; Johansson 2003[3 comparisons]; Savel

14 2005).

15

16 **Participants**

17 The age range of participants across studies (where given) ranged from 16 (Goldberg 1992) to

18 89 years, with the mean age (where given) ranging from 33 to 74 years. For the purpose of

19 this guideline, adult surgical patients are defines as 18 years or over, and whilst the Goldberg

20 (1992) study had an age range from 16 years, the mean age was 43 (inclusion of some

21 children aged between 16 and 18 was not considered important).

22

23 Twelve studies were conducted in the USA (Stone 1981; Youngberg 1985; Conahan 1987;

24 Goldberg 1992; Hynson 1992; Ouellette 1993; Ott 1998; Nguyen 2002; Farley 2004; Hamza

25 2005; Savel 2005; Champion 2006); three in Sweden (Eckerbom 1990; Joachimsson 1987;

26 Johansson 2003); two in Finland (Backlund 1998; Nelskyla 1999); two in Norway (Tølløfsrud

27 1984a; Tølløfsrud 1984b) two in Australia (Mouton 1999; Wills 2001); one in France (Slim

28 1999)and one in Germany (Saad 2000).

29

30 **ASA status**

31 Two studies had patients with ASA I and II status (Slim 1999; Saad 2000; Johansson 2003),

32 one study had patients with either ASA I or II status (Nelskylä 1999), two with ASA I-III status

33 (Goldberg 1992; Bäcklund 1998). One study (Stone 1981) reported a mean ASA status of 2.1.

34 One study (Youngberg 1985) stated that ASA IV patients were not included in the study. ASA

35 status was not reported in the remaining studies.

36

37 **Type of surgery**

38 A range of surgical procedures were undertaken. Laparoscopic gastric bypass (Hamza 2005;

39 Savel 2005; Champion 2006); laparoscopic cholecystectomy (Mouton 1999; Saad 2000;

40 Farley 2004); abdominal aorta (Tølløfsrud 1984a); extra-abdominal vascular surgery

1   (Tølløfsrud 1984b); oral surgery, transsphenoidal hypophysectomy, middle ear surgery or
2   surgery of the pharynx, nose and neck (Eckerbom 1990); laminectomy, major abdominal,
3   major vascular, total hip and radical neck (Stone 1981); kidney transplant (Hynson 1992);
4   minor abdominal surgery (Joachimsson 1987); laporoscopic fundoplication, henioplasty,
5   resection of sigmoid colon or rectopexia (Bäcklund 1998); lower abdominal procedures
6   (Goldberg 1992); cervical or lumbar laminectomy (Ouellette 1993); laparoscopic upper
7   abdominal surgery (Slim 1999); laparoscopic hysterectomy for benign diseases (Nelskylä
8   1999); laporoscopic fundoplication (Wills 2001; Nguyen 2002); laparoscopic gynaecologic
9   procedures (Conahan 1987; Ott 1998); fundoplication (general or urological surgery
10 (Johansson 2003) and type of surgery not stated in one study (Youngberg 1985).

11

12 Type of surgery was stated as elective in eleven studies (Tølløfsrud 1984a; Tølløfsrud 1984b;
13 Conahan 1987; Joachimsson 1987; Goldberg 1992; Slim 1999; Johansson 2003; Hamza
14 2005; Nelskylä 1999; Wills 2001) and not reported in the remaining studies.

15

16 Duration of surgery ranged from 30 minutes to 60 minutes in three studies (Conahan 1987;
17 Nelskyla 1999; Wills 2001); 1 to 3 hours in 16 studies (Tølløfsrud 1984a; Tølløfsrud 1984b;
18 Youngberg 1985; Joachimsson 1987; Goldberg 1992; Hynson 1992; Ouellette 1993; Bäcklund
19 1998; Slim 1999; Nguyen 2002; Johansson 2003; Farley 2004; Hamza 2005; Saad 2000;
20 Savel 2005; Champion 2006) over 3 hours in one study (Stone 1981) and in two studies the
21 range of surgery was 60 minutes to over 3 hours (Goldberg 1992; Ott 1998). Duration of
22 surgery was not reported in the remaining studies.

23

24 In twelve studies (Stone 1981; Tølløfsrud 1984a; Tølløfsrud 1984b; Conahan 1987;
25 Joachimsson 1987; Goldberg 1992; Hynson 1992; Mouton 1999; Nelskylä 1999; Slim 1999;
26 Saad 2000; Wills 2001; Johansson 2003; Hamza 2005; Savel 2005; Champion 2006) patients
27 underwent general anaesthesia. Type of anaesthesia was not stated in the remaining studies.

28

29 **Interventions**
30 **Primary outcomes (including surrogate measures)**
31 One study (Joachimsson 1987) reported incidence of hypothermia.
32 Core temperature was measured:
33 • During the intraoperative period (Tølløfsrud 1984a; Tølløfsrud 1984b; Youngberg 1985;
34   Conahan 1987; Joachimsson 1987; Goldberg 1992; Ouellette 1993; Nguyen 2002;
35   Bäcklund 1998; Mouton 1999; Wills 2001; Johansson 2003; Farley 2004; Hamza 2005);
36 • End of surgery (Hamza 2005; Nelskylä 1999; Saad 2000; Savel 2005; Champion 2006);
37 • Recovery (PACU) (Nelskylä 1999; Nguyen 2002; Farley 2004; Hamza 2005; Champion
38   2006).

39

40 Other outcomes were:

- • Length of stay in PACU (Farley 2004; Hamza 2005; Champion 2006);
- • Length of stay in hospital (Mouton 1999; Slim 1999; Wills 2001;Nguyen 2002);
- • Shivering (Goldberg 1992; Nelskylä 1999;Hamza 2005);
- • Wound infection (Mouton 1998);
- • Perception of pain (Wills 2001; Savel 2005).

Core temperature was measured at the following sites:
- • Tympanic (Hynson 1992; Nelskylä 1999; Johansson 2003);
- • Oesophageal (Tølløfsrud 1984a; Tølløfsrud 1984b; Youngberg 1985; Joachimsson 1987; Ouellette 1993; Mouton 1999; Saad 2000; Nguyen 2002; Farley 2004; Hamza 2005);
- • Pulmonary artery (Bäcklund 1998);
- • Rectal (Eckerbom 1990);
- • Nasopharyngeal (Stone 1981; Wills 2001; Champion 2006);
- • Sublingual (Conahan 1987; Goldberg 1992).

Temperature measurement

Temperature in the Ott (1998) study was measured with an endotracheal temperature probe and Slim (1999) used sub diaphragmatic temperature. Goldberg (1992) recoded intraoperative temperature, using oesophageal and the sublingual methods (standard deviations were not provided for the oesophageal temperature readings). For this reason it was decided to use the sublingual temperature measurements, and results from this study considered in a sensitivity analysis. One study (Savel 2005) did not state site of temperature measurement.

Methodological quality of included studies

In three studies sequence generation was adequate (computer generated random numbers: Hamza 2005; random numbers table: Goldberg 1992; Wills 2001); partially adequate in two studies (computer model: Farley 2004; random numbers: Slim 1999) and unclear in the remaining studies. Allocation concealment was partially adequate in two studies (sealed envelopes: Slim 1999; Nguyen 2002) and unclear in the remaining studies.

Eight studies reported that the study was double blind (Ott 1998; Nelskylä 1999; Slim 1999; Wills 2001; Farley 2004; Hamza 2005; Savel 2005; Champion 2006).

Three studies (Farley 2004; Hamza 2005; Nelskylä 1999) reported dropouts less than 20%. In one study (Farley 2004) with 117 patients were excluded from analysis due to changes in operation type (n=16), extensive lysis of adhesions (n=2), and removal of device due to technical reasons (n=2). The Farley (2004) study did not provide number of patients excluded from analysis by each group. In one study (Hamza 2005), patients in the usual care group were excluded from analysis because forced air warming was instituted as core temperature was below 34°C (n=2/21) and conversion to open procedures (n=4). In Nelskylä (1999), one

1 patient (unclear from which group) was excluded from analysis as an outlier because of
2 surgical problems.
3
4 Baseline comparability was demonstrated by:
5 • Age;
6 • Duration of surgery;
7 • Core temperature.
8
9 Exceptions are noted below.
10
11 There were no differences in baseline core temperatures in ten studies (Joachimsson 1987;
12 Eckerbom 1990; Goldberg 1992 [2 comparisons]; Ouellette 1993; Backlund 1998; Wills 2001;
13 Nguyen 2002; Johansson 2003 [3 comparisons]; Savel 2005; Champion 2006). Of these, in
14 four studies (Backlund 1998; Wills 2001; Nguyen 2002; Savel 2005) patients in either the
15 intervention or the control groups were hypothermic (Figures 1a and 1b). These studies were
16 excluded from the analyses.
17
18 **Figure 1a: Baseline core temperature: insufflation gas**

Review: IPH Insufflation
Comparison: 01 Warmed insufflation gas versus standard care- Baseline Core temperature
Outcome: 01 Baseline Core temperature

Study or sub-category	N	Warmed CO2 Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Backlund 1998	13	35.60(0.30)	13	35.50(0.40)		20.91	0.10 [-0.17, 0.37]
Champion 2006	25	36.30(0.40)	25	36.40(0.50)		24.52	-0.10 [-0.35, 0.15]
Nguyen 2002	10	35.90(0.40)	10	35.70(0.60)		7.73	0.20 [-0.25, 0.65]
Savel 2005	15	35.80(0.50)	15	36.00(0.40)		14.71	-0.20 [-0.52, 0.12]
Wills 2001	19	35.90(0.40)	22	35.80(0.30)		32.13	0.10 [-0.12, 0.32]

-1 -0.5 0 0.5 1
Favours usual care   Favours warming

19
20
21 **Figure 1b: Baseline core temperature: inspired gas**
22

Review: IPH Heated humidifier
Comparison: 05 Baseline Core temperature- Heated-Humidifier
Outcome: 01 Baseline Core temperature

Study or sub-category	N	Warmed Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Eckerbom 1990	10	36.70(0.50)	10	36.60(0.50)		0.84	0.10 [-0.34, 0.54]
Goldberg 1992	14	36.80(0.50)	16	36.90(0.50)		1.25	-0.10 [-0.46, 0.26]
Goldberg 1992HME	21	36.90(0.50)	16	36.90(0.50)		1.52	0.00 [-0.33, 0.33]
Joachimsson 1987	23	36.84(0.40)	24	36.90(0.50)		2.40	-0.06 [-0.32, 0.20]
Johansson 2003	15	36.90(0.10)	15	36.90(0.10)		31.33	0.00 [-0.07, 0.07]
Johansson3.01 2003	15	36.90(0.10)	15	36.90(0.10)		31.33	0.00 [-0.07, 0.07]
Johansson6.01 2003	15	36.90(0.10)	15	36.90(0.10)		31.33	0.00 [-0.07, 0.07]

-1 -0.5 0 0.5 1
Favours usual care   Favours warming

23
24

1	Baseline core temperature was not reported in six studies (Stone 1981; Youngberg 1985;
2	Hynson 1992; Mouton 1999; Slim 1999; Farley 2004). In one study (Hamza 2005) baseline
3	core temperature was extracted from the graph (warmed: 36.54°C; usual care: 36.80°C) but
4	as standard deviations were not provided we could not determine if the difference was
5	statistically significant. In one study (Saad 2000) the preoperative temperature was provided,
6	but the standard deviations were very large (warmed: 36°C [SD 45] and unwarmed: 36.2°C
7	[SD160]) which was noted as an error in reporting, meaning we could not determine whether
8	this difference was significant. In one study (Nelskylä 1999) baseline core temperature
9	(beginning of anaesthesia) was reported and the confidence interval for mean (37°C [95% CI:
10	36.8; 37.2] and 37.2°C [95% CI of mean: 37.0; 37.3] for the warmed and unwarmed groups
11	respectively) and the authors reported that no significant difference was indicated. In one
12	study (Ott 1998) baseline core temperature was reported for the warmed group (36.3°C) and
13	data extracted from the graph showed that the baseline temperature was 36.4°C for the usual
14	care group. Standard deviations were not reported so we were unable to determine if the
15	difference was significant. In two studies (Tølløfsrud 1984a; Tølløfsrud 1984b) there was one
16	baseline temperature point reported for all groups. The baseline mean core temperature
17	extracted from the graph was 36.8°C for both groups.
18	
19	There was a significant difference in duration of surgery and (25 minutes longer) in the control
20	group (Savel 2005).
21	
22	There was comparability in volume of insufflation gas between the groups in eight studies
23	(Backlund 1998; Slim 1999; Saad 2000; Nguyen 2002; Farley 2004; Hamza 2005; Champion
24	2006; Wills 2001) (Figures 2a and 2b). In Farley (2004) the volume of insufflation gas was 67
25	litres and 64 litres for the warmed and the usual care groups respectively. Results for Farley
26	(2004) are shown separately in Figure 2b as only the mean values and p-value was reported.
27	
28	One study (Mouton 1999) reported that an average of 10 litres or more CO_2 insufflation was
29	required for the humidified group versus the usual care group, however, standard deviations
30	were not provided so we cannot determine if this difference is statistically significant.
31	
32	One study (Nelskylä 1999) reported medians and range and reported that there was no
33	significant differences [heated group: 128 litre (43-199); warmed group: 120 litre (65-279).
34	One study (Ott 1998) with three types of procedures only reported that CO_2 gas volume used
35	in both groups for just one procedures (warmed:66.4 litre; usual care:95.5 litre); of the
36	remaining two procedures volume of insufflation gas for the heated group was reported for
37	one procedure but not reported for the usual care group. Savel (2005) did not report the
38	volume of insufflation gas.
39	
40	**Figure 2a: Volume of insufflation gas**
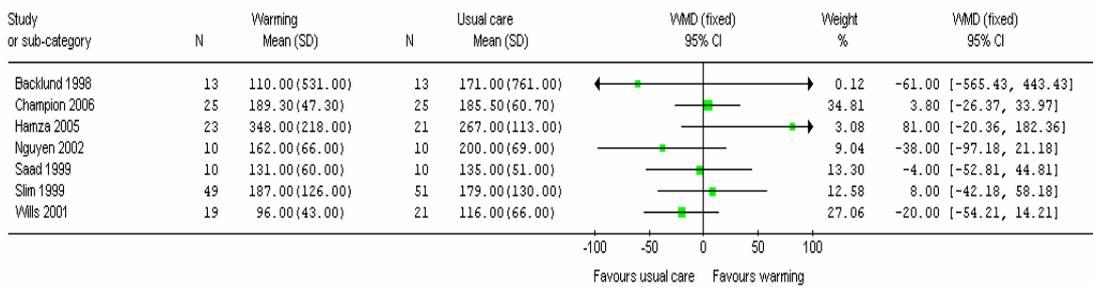
NB: Scale -100 to 100

Figure 2b: Volume of insufflation gas
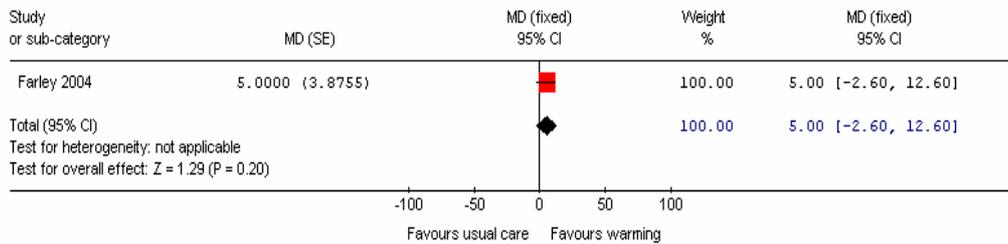
NB: Scale -100 to 100

Six studies conducted a power calculation (Farley 2004; Hamza 2005; Slim 1999; Saad 2000; Wills 2001; Savel 2005). In Farley (2005), the study was powered to detect 0.31°C in the mean intraoperative core temperature and 0.35°C in the mean core temperature change during the operation at an 80% level. One study (Saad 2000) stated that power of study was calculated under assumption that loss of 1°C in core or intra-abdominal temp. It did not indicate at what level and power the analysis was conducted. In Hamza (2005) power analysis was based on a 50% reduction in opioid analgesic requirement in the PACU assuming 10mg (SD5) by control group at power of 0.09 (alpha=0.05). The Slim (1999) study used shoulder tip pain as the primary outcome in detecting at least 1 SD difference with a statistical power of 0.99 at a significance level (2-tailed) of 0.01, showed that at least 49 patients were required in each group. Savel (2005) used a two-tailed unpaired t-test with a probability at 5% level 80% power to detect a difference of 11mg (SD 10) of morphine utilisation at 24 hour needed to recruit 15 patients in each group. The Wills (2001) study aimed to detect a reduction in postoperative morphine consumption by 30% at 90% confidence, required 40 patients.

Summary

Five studies were identified at risk of bias (Goldberg 1992; Nelskylä 1999; Farley 2004; Hamza 2005; Savel 2005). Three studies (Farley 2004; Nelskylä 1999; Hamza 2005) reported

dropouts (less than 20%), one study (Savel 2005) was not comparable as the duration of surgery was significantly longer by 25 minutes for the usual care group, and one study (Goldberg 1992) used sublingual temperature recordings (less reliable). All of these studies were considered in sensitivity analyses.

The following comparisons were reported:

A. Warmed insufflation gas versus standard care

- Heated-humidified CO_2 (35°C; 95%) versus cold-dry CO_2 (Champion 2006);
- Heated-humidified CO_2 versus room temperature-non-humidified CO_2 (Farley 2004);
- Heated-humidified CO_2 (37°C; 95%) versus room temperature CO_2 (Hamza 2005);
- Warmed-humidified CO_2 (34 to 37°C; 88-90%) versus room temperature CO_2 (21.2°C to 25.2°C; humidity: 0 to 5%) (Mouton 1999);
- Heated-humidified CO_2 (37°C) versus unwarmed CO_2 (24°C) (humidity: 12 to 14mmHg) (Nelskylä 1999);
- Heated CO_2 (37°C) versus cold CO_2 (21°C) (Saad 2000);
- Warmed-humidified CO_2(35°C; 95%) versus room temperature non-humidified CO_2 (Savel 2005);
- Warmed-humidified CO_2 (35°C; 95%) versus room temperature non-humidified CO_2 (Ott 1998)*

  * Results from this study will not be included in the analysis as the results were provided separately for three procedures, however, the number of patients within each subgroup was not provided.

B. Warmed insufflation gas versus standard care with active patient warming in both groups

- Pre-warmed CO_2 versus room temperature CO_2 (Backlund 1998)
  + Warm water bath mattress (39°C);
- Heated-humidified CO_2 (37°C; 95%) versus room temperature CO_2 (<5% humidity) (Nguyen 2002)
  + Forced air warming (upper body) (setting not stated) in both groups;
- Warmed-humidified CO_2 (22°C to 30.5°C) versus standard CO_2 (Wills 2000)
  + Forced air warming (upper body) (setting not stated) in both groups.

C. Warmed inspired gas versus usual care

- Heated-humidifier (37°C) versus usual care (no device) (Goldberg 1992)
  + Room temperature fluids and warmed blood (36°C);
- Heated-humidifier (40°C) versus usual care (Hynson 1992)
  + Warmed IV fluids (37°C);
- Heated-humidifier (38°C) versus usual care (Hynson 1992)
  + Warmed fluids (temperature not stated) and blood (37°C to 38°C);

- Heated-humidifier (35°C to 37°C) versus usual care (no device) (Youngberg 1985);
- Heat and moisture exchange (temperature not stated) versus usual care (no devices) (Goldberg 1992)
  + Room temperature fluids and warmed blood (36°C);
- Heat and moisture exchanger versus usual care (no device)
  At the following flow rates:
  - o $1.0\,\text{min}^{-1}$ (Johansson 2003a);
  - o $3.0\,\text{min}^{-1}$ (Johansson 2003b);
  - o $6.0\,\text{min}^{-1}$ (Johansson 2003c)
- Heated-humidified inspired gases (37°C; 100%) versus standard care (no added humidity nor heat) (Stone 1981)
  - o Patients received circulating-water warming blankets (38°C) at the discretion of the anaesthesiologist. It is unclear how many patients in each group received a warming blanket. The study may be confounded and will not be considered for further analysis.

D. Warmed inspired gas versus usual care; with thermal insulation in both groups
- Heat and moisture exchanger (34°C; Relative humidity: 100%) versus room temperature inspired gas (23°C; Relative humidity: 1%) (Eckerbom 1990) + aluminium blanket in both groups + IV fluids (room temperature).

RESULTS
The guideline development group (GDG) originally decided to stratify only by presence/absence of comorbidities, trauma, and hyperthermia. Perioperative phases were also to be considered separately, as were insufflation and inspired gases. Post-hoc analysis to stratify by type of anaesthesia (general; regional; combined) was conducted, as these were expected to have different mechanisms of action. Initially, the GDG decided to combine all comparisons of active gas warming versus usual care, regardless of the presence of other active patient interventions.

A. Warmed insufflation gas versus standard care

General anaesthesia
Six studies (Mouton 1999; Nelskyla 1999; Saad 2000; Farley 2004; Champion 2005; Hamza 2005) compared warmed insufflation gas with standard insufflation.

1. Intraoperative core temperature
Six studies reported intraoperative core temperature (Bäcklund 1998; Mouton 1999; Wills 2001; Nguyen 2002; Farley 2004; Hamza 2005). In three studies (Bäcklund 1998; Wills 2001; Nguyen 2002) were hypothermic at baseline so results will not be included.

1

2 One study (Hamza 2005) reported core temperature at 30 minutes, 60 minutes and end of

3 insufflation, one study (Farley 2004) provided change in intraoperative temperature and one

4 study (Mouton 1999) only reported change in temperature during pneumo peritoneum (gastric

5 insufflation) but no standard deviations were reported. Results for the three studies were not

6 combined (Figure 3).

7

8 In one study (Hamza 2005) there was no significant difference in core temperature at 30 and

9 60 minutes. At end of insufflation (over 90 minutes) the mean core temperature was

10 significantly higher for the warmed group: MD 0.59°C (95% CI 0.22, 0.96) for a control group

11 temperature 35.0°C, but wide confidence interval were noted. One study (Farley 2004)

12 showed a significantly less change in mean core temperature for the warmed group: MD

13 0.32°C (95% CI 0.13, 0.51) with a change in control group temperature of -0.03°C. We note

14 that the study reported mean intraoperative temperature was 36.0°C in both groups.

15

16 One study (Mouton 1999) reported that there was no significant difference in decrease to

17 mean temperature during pneumo peritoneum (0.25°C in the warmed group and 0.3°C in the

18 usual care group). We note duration of pneumo peritoneum was 40 minutes in the warmed

19 group and 48.3 minutes in the usual care group. No decision was reached whether this was

20 clinically significant.

21

22 **Figure 3: Intraoperative core temperature; warmed insufflation versus usual care;**

23 **general anaesthesia**
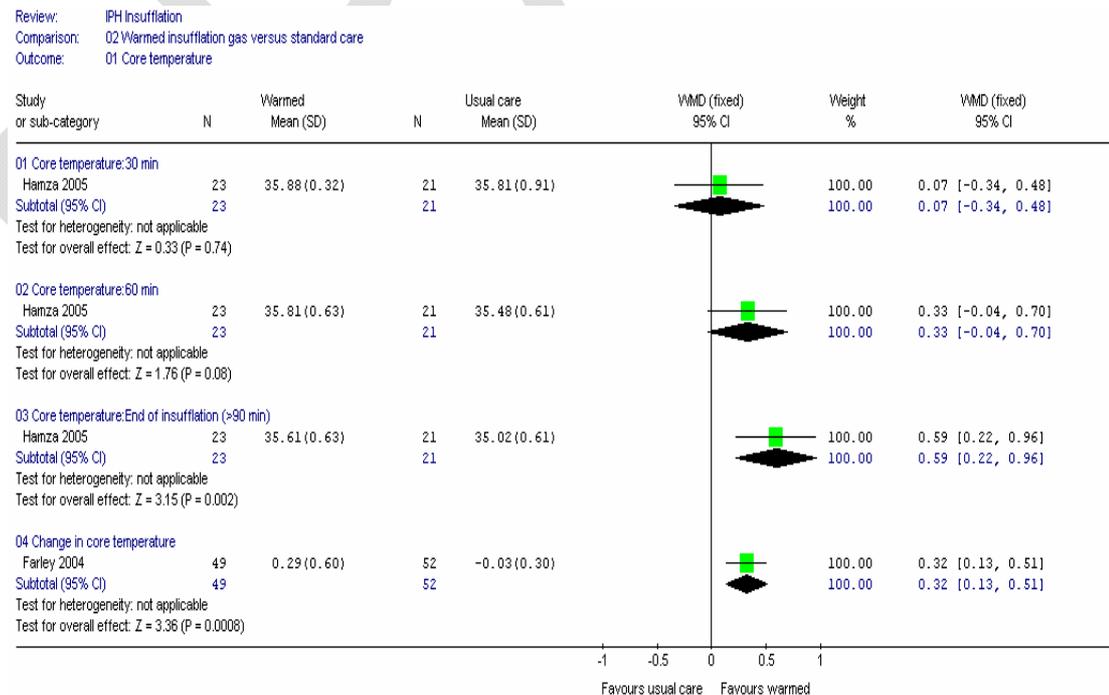
24

25

26 **2. Core temperature: End of surgery**

1 Three studies reported core temperature at end of surgery (Hamza 2005; Nelskylä 1999; Saad

2 2000). Duration of surgery was less than 2 hours in two studies (Nelskylä 1999; Saad 2000),

3 and greater than 2 hours (Hamza 2005). One study (Nelskylä 1999) did not report standard

4 deviations and results were not combined with the remaining three studies for this reason.

5

6 One study (Nelskylä 1999) reported mean core temperature of 36.1°C and 36.3°C for the

7 warmed and usual care groups respectively.

8

9 Meta-analysis of two studies (Hamza 2005; Saad 2000) with 65 patients showed a

10 significantly higher core temperature: MD 0.51°C (95% CI 0.31, 0.70) for the warmed group,

11 with control group temperature range reported at 35.0°C to 35.7°C. The difference was

12 clinically significant and no heterogeneity was observed (Figure 4).

13

14 **Figure 4: Core temperature: end of surgery; warmed insufflation versus usual care;**

15 **general anaesthesia**

16

17
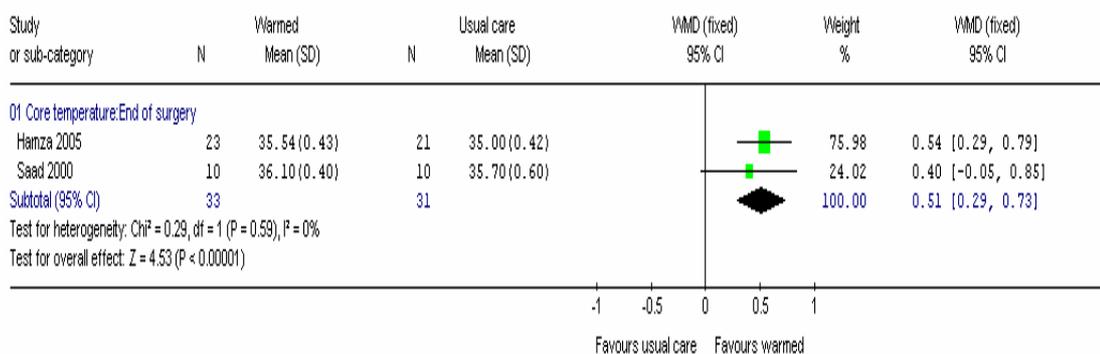
18 **Postoperative outcomes**

19 **3. Core temperature: PACU**

20 Four studies (Bäcklund 1998; Nelskylä 1999; Nguyen 2002; Farley 2004; Hamza 2005;

21 Champion 2005) reported core temperature in PACU. In two studies (Bäcklund 1998; Nguyen

22 2002) patients were hypothermic at baseline and therefore results were not included. Results

23 for Nelskylä (1999) are not combined as standard deviations were not reported (Figure 5).

24

25 Meta-analysis of two studies (Farley 2004; Champion 2006) with 151 patients showed no

26 significant difference in core temperature at entry into PACU. After 30 minutes in PACU, one

27 study (Hamza 2005) with 44 patients showed no significant difference in core temperature.

28 After 60 minutes in PACU, meta-analysis of two studies (Farley 2004; Hamza 2005) with 145

29 patients showed no significant difference. After 4 hours in the PACU, one study (Farley 2004)

30 with 111 patients showed no significant difference in core temperature.

31

1 In one study (Nelskylä 1999) 15 minutes after entry into PACU the core temperature was
2 0.4°C higher in the unwarmed group, however, we cannot determine if this was statistically
3 significant as the standard deviations were not provided. At 75 minutes in PACU, the core
4 temperature was 0.1°C higher in the unwarmed group.
5
6 **Figure 5: Core temperature: PACU; warmed insufflation versus usual care; general**
7 **anaesthesia**

Review: IPH Insufflation
Comparison: 02 Warmed insufflation gas versus standard care
Outcome: 03 Core temperature: PACU

Study or sub-category	N	Warmed Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 Core temperature:Entry into PACU							
Champion 2006	25	36.30(0.40)	25	36.40(0.50)		46.53	-0.10 [-0.35, 0.15]
Farley 2004	49	35.90(0.60)	52	36.00(0.60)		53.47	-0.10 [-0.33, 0.13]
Subtotal (95% CI)	74		77			100.00	-0.10 [-0.27, 0.07]
Test for heterogeneity: Chi² = 0.00, df = 1 (P = 1.00), I² = 0%							
Test for overall effect: Z = 1.14 (P = 0.25)							
03 30 min in PACU							
Hamza 2005	23	35.72(0.65)	21	35.40(0.62)		100.00	0.32 [-0.06, 0.70]
Subtotal (95% CI)	23		21			100.00	0.32 [-0.06, 0.70]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 1.67 (P = 0.09)							
04 60 min in PACU							
Farley 2004	49	36.30(0.70)	52	36.30(0.60)		49.27	0.00 [-0.25, 0.25]
Hamza 2005	23	35.90(0.43)	21	35.72(0.42)		50.73	0.18 [-0.07, 0.43]
Subtotal (95% CI)	72		73			100.00	0.09 [-0.09, 0.27]
Test for heterogeneity: Chi² = 0.97, df = 1 (P = 0.32), I² = 0%							
Test for overall effect: Z = 1.00 (P = 0.32)							
06 4 hours in PACU							
Farley 2004	49	36.60(0.50)	52	36.70(0.50)		100.00	-0.10 [-0.30, 0.10]
Subtotal (95% CI)	49		52			100.00	-0.10 [-0.30, 0.10]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 1.00 (P = 0.32)							

-1   -0.5   0   0.5   1
Favours usual care   Favours warmed

8
9

10 **4. Shivering**
11 Two studies (Nelskyla 1999; Hamza 2005) reported postoperative shivering. In Nelskyla
12 (1999) shivering was evaluated upon arrival to the PACU by a nurse blinded to the treatment.
13 The study reported 33.4% of all the patients (n=37) exhibited shivering which disappeared
14 within 60 minutes. The study also reported that one patient in the unwarmed group required
15 meperidine for shivering.
16
17 One study (Hamza 2005) with 44 patients reported incidence of shivering in the postoperative
18 period. Details on how shivering was assessed were not provided. The incidence of shivering
19 was significantly less in the warmed group (OR 0.11 (95% CI 0.01, 0.80), corresponding to a
20 NNT (Numbers needed to treat) of 6 (95% CI 3,100). It is noted that the confidence interval is
21 wide (Figure 6).
22
23 **Figure 6: Incidence of shivering; warmed insufflation versus usual care; general**
24 **anaesthesia**

Review: IPH Insufflation
Comparison: 02 Warmed insufflation gas versus standard care
Outcome: 04 Incidence of shivering
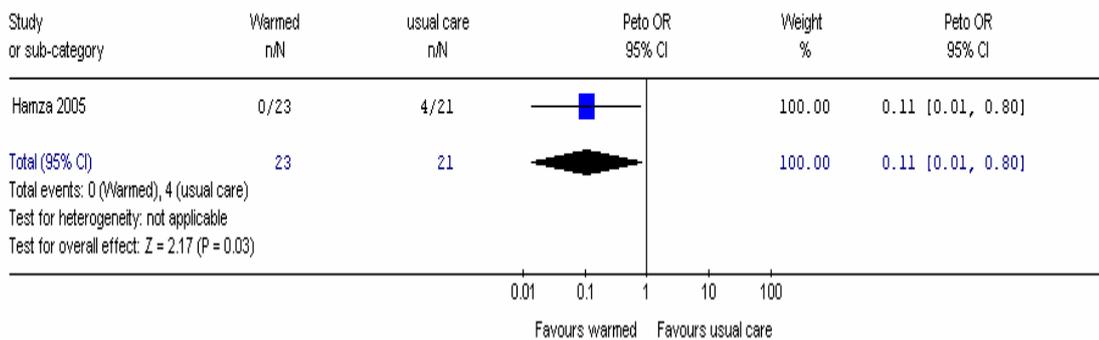
NB: Scale 0.01 to 100

5. Length of stay in PACU

Meta-analysis of three studies (Farley 2004; Hamza 2005; Champion 2006) with 195 patients reported length of stay in PACU. There was no significant difference in length of stay between the two groups (Figure 7).

Figure 7: Length of stay in PACU; warmed insufflation versus usual care; general anaesthesia

Review: IPH Insufflation
Comparison: 02 Warmed insufflation gas versus standard care
Outcome: 05 Length of stay in PACU
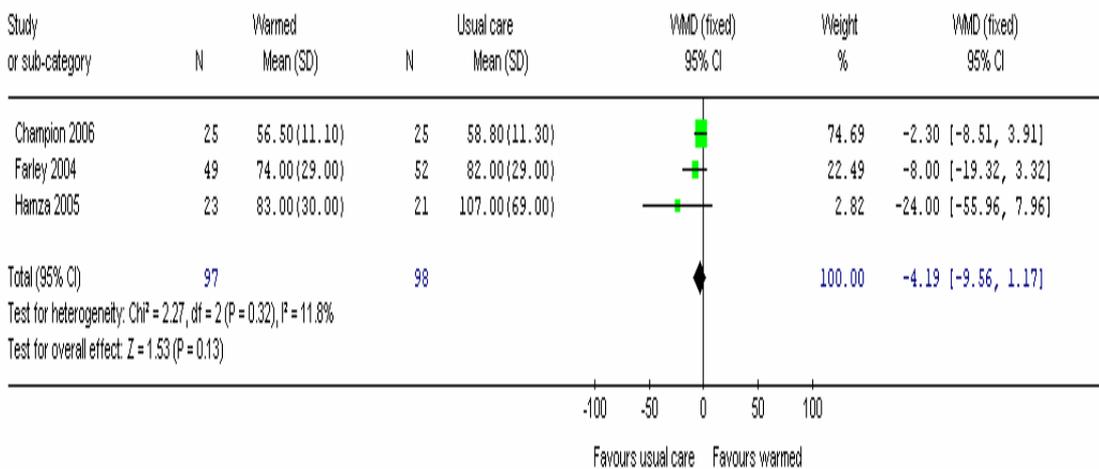
NB: Scale -100 to 100

6. Length of hospital stay

Seven studies (Mouton 1998; Slim 1999; Wills 2001; Nguyen 2002; Farley 2004; Hamza 2005; Champion 2006) reported length of stay in hospital. Results for Wills (2001) and Nguyen (2002) will not be included in the analysis as patients were hypothermic at baseline.

Mouton (1998) reported that there was no difference in length of stay (warmed: 1.5 days; unwarmed: 2.1 days), however, standard deviations were not reported therefore we cannot determine if this difference was statistically significant. In one study (Hamza 2005) only the mean and range was provided: (warmed: 2 days (range 2-2); unwarmed: 2 days (range 2 to 3). Meta-analysis of the remaining three studies (Slim 1999; Farley 2004; Champion 2006) with 251 patients showed no significant difference (Figure 8).

Figure 8: Length of stay in hospital; warmed insufflation versus usual care; general anaesthesia

Review: IPH Insufflation
Comparison: 02 Warmed insufflation gas versus standard care
Outcome: 06 Length of hospital stay

Study or sub-category	N	Warmed Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Champion 2006	25	2.30 (0.50)	25	2.30 (0.50)		51.27	0.00 [-0.28, 0.28]
Farley 2004	49	1.29 (0.92)	52	1.21 (1.04)		26.93	0.08 [-0.30, 0.46]
Slim 1999	49	2.90 (1.30)	51	2.70 (0.80)		21.80	0.20 [-0.23, 0.63]
Total (95% CI)	123		128			100.00	0.07 [-0.13, 0.26]

Test for heterogeneity: Chi² = 0.60, df = 2 (P = 0.74), I² = 0%
Test for overall effect: Z = 0.64 (P = 0.52)

-1   -0.5   0   0.5   1

Favours usual care   Favours warmed

7. Wound infection

One study (Mouton 1998) with 26 patients reported that was one case of minor wound infection was reported in each group. Definition of wound infection and how it was assessed was not stated.

B. Warmed inspired gases versus usual care

Five studies (Youngberg 1985; Joachimsson 1987; Goldberg 1992; Hynson 1992; Johansson 2003) compared warmed inspired gases with usual care.

1. Incidence of hypothermia

One study (Joachimsson 1987) reported incidence of hypothermia at three different temperature range (35.9°C to 35.0°C; 34.9°C to 34.0°C; less 34.0°C) at the end of surgery. It was decided to combine the number of events. There was a significantly lower incidence of hypothermia in the warmed group [RR 0.06 (95% 0.01, 0.28], a NNT of 2 (95% CI 1, 2) for a control group rate 100% (18/18) (Figure 9).

Figure 9: Incidence of hypothermia; warmed insufflation versus usual care + active warming in both groups; general anaesthesia

```
Review:        IPH Heated humidifier
Comparison:    02 Incidence of hypothermia
Outcome:       01 Incidence of hypothermia

Study                    Warming      Usual care        RR (fixed)         Weight        RR (fixed)
or sub-category            n/N           n/N             95% CI              %            95% CI

01 All range
  Joachimsson 1987         1/25          18/18            ■                 100.00      0.06 [0.01, 0.28]
Subtotal (95% CI)          25            18             ◆                    100.00      0.06 [0.01, 0.28]
Total events: 1 (Warming), 18 (Usual care)
Test for heterogeneity: not applicable
Test for overall effect: Z = 3.56 (P = 0.0004)

                                            0.001  0.01  0.1   1   10  100  1000
                                             Favours warming   Favours usual care
```
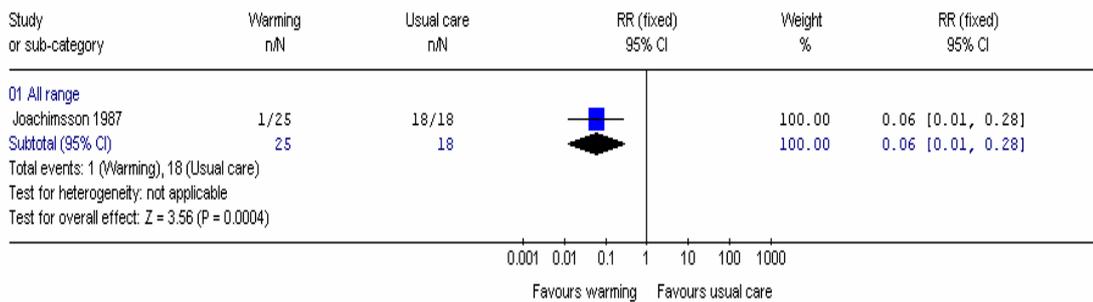
NB: Scale 0.01 to 1000

2. Intraoperative core temperature

Eight studies (Stone 1981; Tølløfsrud 1984a; Tølløfsrud 1984b; Youngberg 1985;
Joachimsson 1987; Goldberg 1992; Hynson 1992; Ouellette 1993) comparing heated-
humidifiers with usual care and two studies comparing heat and moisture exchanger with
usual care (Goldberg 1992; Johansson 2003) reported intraoperative core temperature. One
study (Youngberg 1985) did not report standard deviations and we cannot therefore determine
if the differences observed in core temperature was significant. In one study (Stone 1981)
patients received warmed blankets at the discretion of the anaesthetist. The results for this
study may be confounded and will not be considered in the analyses.

At 30 minutes three studies (Conahan 1987; Joachimsson 1987; Ouellette 1993) with 90
patients showed borderline significance and a small significantly higher core temperature for
the warmed group: MD 0.19°C (95% 0, 0.38) for a control group temperature range of 35.9°C
to 36.0°C. There was no heterogeneity. The results for Conahan (1987) were considered in a
sensitivity analysis (temperature measured at the sublingual site). The odds ratio for the
Conahan (1987) study was large and significant compared to that for the other two studies
(Joachimsson 1987; Ouellette 1993) which showed no significant difference, no heterogeneity
was noted. A further sensitivity analysis excluding the Conahan (1987) study was conducted.
Meta-analysis of the remaining two studies (Joachimsson 1987; Ouellette 1993) with 71
patients resulted in no significant difference and no significant heterogeneity (Figure 10).

In one study (Youngberg 1985) with 40 patients the change in core temperature at 30 minutes
was extracted: heated-humidified group: -0.11°C; control group: -0.26°C. Baseline core
temperature was not reported or standard deviations, so statistical significance is not
determined.

At 60 minutes, meta-analysis of eight studies [10 comparisons] (Tølløfsrud 1984a; Tølløfsrud
1984b; Joachimsson 1987; Goldberg 1992 [2 comparisons]; Hynson 1992; Ouellette 1993;
Johansson 2003 [3 comparisons]) showed significantly higher mean core temperature for the

warmed group: WMD 0.12°C (95% CI 0.03, 0.21) when compared to the control group temperature of 35.5°C to 36.0°C. There was no significant heterogeneity (I^2=13.2%, p=0.32).

One study (Youngberg 1985) only reported change in core temperature (warmed group: -0.22°C; control group: -0.80°C) and did not report standard deviations so we cannot report whether the difference in core temperatures was significant.

At 2 hours, for 5 studies [7 comparisons] (Tølløfsrud 1984a; Tølløfsrud 1984b; Joachimsson 1987; Hynson 1992; Johansson 2003 [3 comparisons]) with 187 patients the mean core temperature was significantly higher for the warmed group: WMD 0.42°C (95% CI 0.24, 0.59) for a control group temperature of 35.2°C to 35.8°C. There was significant heterogeneity (I^2=64.1%, p=0.01). Observed heterogeneity at 2 hours was considered by the proposed factors for subgroup analyses. We note there was limited demographic information in two studies (Tølløfsrud 1984a; Tølløfsrud 1984b).

Five studies (Tølløfsrud 1984a; Tølløfsrud 1984b Joachimsson 1987; Hynson 1992; Johansson 2003 [3 comparisons]) were similar in age (less than 65 years) and the mean age was over 65 in one study (Tølløfsrud 1984b), type of surgery (elective for all studies), and duration of surgery (3 hours for all studies). ASA status was reported in only one study (Johansson 2003: ASA I-II).

In terms of factors specific to the warming devices, four studies used a heated-humidifier (Tølløfsrud 1984a; Tølløfsrud 1984b; Joachimsson 1987; Hynson 1992) and one instituted a heat and moisture exchanger (Johansson 2003). The temperature settings was not stated in three studies (Tølløfsrud 1984a; Tølløfsrud 1984b; Johansson 2003) and were as follows in the remaining two studies: 38°C (Joachmisson 1987); 40°C (Hynson 1992); and the fresh gas flow was not stated in three studies (Tølløfsrud 1984a; Tølløfsrud 1984b; Joachimsson 1987) and were maintained at: 5 L/min (Hynson 1992) and 1 to 6 L/min (Johansson 2003).

None of subgroup analyses adequately explained the observed heterogeneity. Only two studies (Tølløfsrud 1984a; Joachimsson 1987) showed a statistically significant difference in core temperature.

3. Core temperature: end of surgery

At end of surgery, two studies (Joachmisson 1987; Ouellette 1993) with 71 patients reported core temperature. Mean duration of surgery was over 2 hours in both of the studies. The mean core temperature was significantly higher for the warmed group: MD 0.45°C (95% CI 0.08, 0.82) for a control group temperature 35.4°C. The difference was clinically significant. The confidence interval is fairly wide (Figure 10).

1   **Figure 10: Intraoperative core temperature; warmed inspired gases versus usual care;**

2   **general anaesthesia**

Review: IPH Heated humidifier
Comparison: 01 Intraoperative Core temperature
Outcome: 01 Core temperature

Study or sub-category	N	Warmed Mean (SD)	N	Usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 Core temperature- 30 min							
Conahan 1987	10	36.20(0.32)	9	35.90(0.30)		46.05	0.30 [0.02, 0.58]
Joachimsson 1987	23	36.23(0.41)	24	36.14(0.73)		31.58	0.09 [-0.25, 0.43]
Ouellette 1993	12	36.10(0.50)	12	36.00(0.50)		22.37	0.10 [-0.30, 0.50]
Subtotal (95% CI)	45		45			100.00	0.19 [0.00, 0.38]

Test for heterogeneity: Chi² = 1.13, df = 2 (P = 0.57), I² = 0%
Test for overall effect: Z = 1.96 (P = 0.05)

02 Core temperature- 60 min							
Hynson 1992	5	-1.01(0.23)	5	-1.08(0.23)		11.33	0.07 [-0.22, 0.36]
Joachimsson 1987	23	36.23(0.41)	24	36.14(0.73)		8.13	0.09 [-0.25, 0.43]
Johansson 2003b	15	35.72(0.25)	15	35.69(0.25)		28.78	0.03 [-0.15, 0.21]
Johansson 2003c	15	35.69(0.25)	15	35.50(0.31)		22.68	0.19 [-0.01, 0.39]
Johansson2003a	15	35.88(0.31)	15	35.59(0.37)		15.44	0.29 [0.05, 0.53]
Ouellette 1993	12	36.00(0.70)	12	35.90(0.60)		3.39	0.10 [-0.42, 0.62]
Tollofsrud 1984a	10	35.81(0.55)	10	35.70(0.64)		3.37	0.11 [-0.41, 0.63]
Tollofsrud 1984b	10	36.25(0.37)	10	36.01(0.46)		6.88	0.24 [-0.13, 0.61]
Subtotal (95% CI)	105		106			100.00	0.14 [0.04, 0.23]

Test for heterogeneity: Chi² = 3.77, df = 7 (P = 0.81), I² = 0%
Test for overall effect: Z = 2.76 (P = 0.006)

03 Core temperature- 2 hours							
Hynson 1992	5	-1.66(0.47)	5	-1.50(0.47)		8.68	-0.16 [-0.74, 0.42]
Joachimsson 1987	23	36.01(0.51)	24	35.24(0.52)		33.96	0.77 [0.48, 1.06]
Johansson 2003b	15	35.50(0.60)	15	35.30(0.70)		13.53	0.20 [-0.27, 0.67]
Johansson 2003c	15	35.45(0.80)	15	35.30(0.90)		7.93	0.15 [-0.46, 0.76]
Johansson2003a	15	35.80(0.60)	15	35.80(0.60)		15.97	0.00 [-0.43, 0.43]
Tollofsrud 1984a	10	36.16(0.55)	10	35.32(0.73)		9.18	0.84 [0.27, 1.41]
Tollofsrud 1984b	10	36.16(0.55)	10	35.67(0.64)		10.76	0.49 [-0.03, 1.01]
Subtotal (95% CI)	93		94			100.00	0.42 [0.24, 0.59]

Test for heterogeneity: Chi² = 16.70, df = 6 (P = 0.01), I² = 64.1%
Test for overall effect: Z = 4.76 (P < 0.00001)

04 Core temperature-End of surgery							
Joachimsson 1987	23	36.10(0.50)	24	35.40(1.20)		49.99	0.70 [0.18, 1.22]
Ouellette 1993	12	35.90(0.70)	12	35.70(0.60)		50.01	0.20 [-0.32, 0.72]
Subtotal (95% CI)	35		36			100.00	0.45 [0.08, 0.82]

Test for heterogeneity: Chi² = 1.76, df = 1 (P = 0.18), I² = 43.3%
Test for overall effect: Z = 2.39 (P = 0.02)

-4   -2   0   2   4
Favours usual care   Favours warmed

3

4   NB: Scale -4 to 4

5

6   **4. Core temperature: PACU**

7   Two studies (Conahan 1987: 3 comparisons; Goldberg 1992: 2 comparisons) with 70 patients

8   reported sublingual temperature at entry in PACU. The mean core temperature was

9   significantly higher for the warmed group:MD 50°C (95% CI 0.26, 0. 74) for a control group

10   temperature of 35.3°C to 35.4°C. The difference was clinically significant. There was no

11   heterogeneity (Figure 11).

12

13   **Figure 11: Core temperature: PACU; warmed inspired gases versus usual care; general**

14   **anaesthesia**
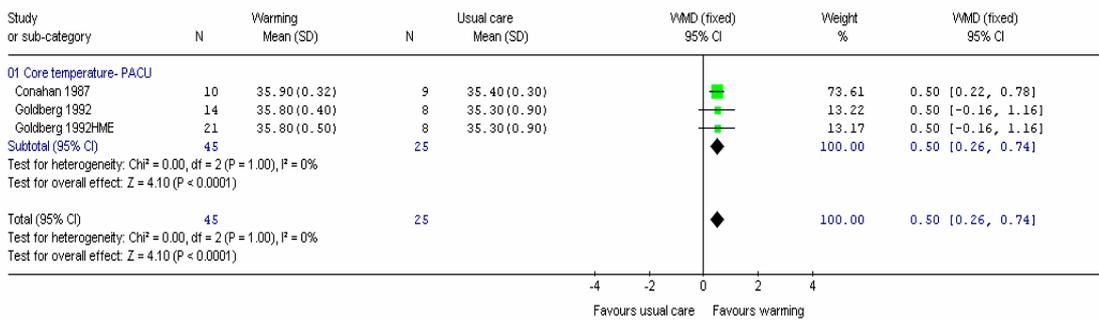
NB: Scale -4 to 4

5. Incidence of shivering

Two studies (Conahan 1987: 3 comparisons]; Goldberg 1992: 2 comparisons) reported presence of shivering in PACU. Shivering was assessed by nurses blinded to the treatment. The mean difference in the incidence of shivering was not significant (Figure 12).

Figure 12: Incidence of shivering; warmed inspired gases versus usual care; general anaesthesia
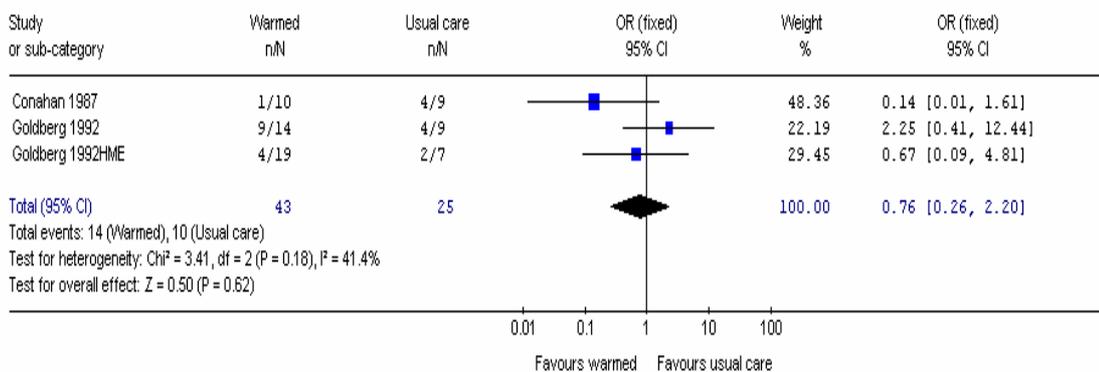
NB: Scale -0.01 to 100

6. Thermal discomfort: perception of feeling cold

Two studies (Conahan 1987: 3 comparisons; Goldberg 1992: 2 comparisons) reported patients' perception of feeling cold. The number of patients feeling cold was significantly less in the warmed group [RR 0.23 (95% CI 0.07, 0. 70). This corresponded to an NNT of 3 (95% CI 2, 8) (Figure 13).

Figure 13: Thermal discomfort; warmed inspired gases versus usual care;
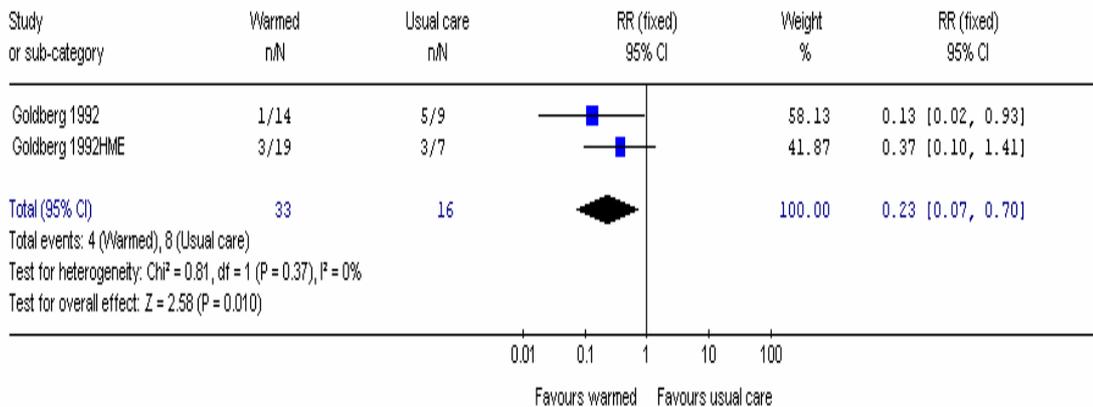
NB: Scale 0.01 to 100

C. Warmed inspired gas versus usual care; with thermal insulation in both groups

1. Core temperature

One study (Eckerbom 1990) reported core temperature at 45 minutes after induction and 20 minutes after end of anaesthesia. At 45 minutes, the change in core temperature was -0.3°C and -0.2°C (1 SD for core temperature $\leq$0.3°C) for the warmed and usual care groups respectively. At 20 minutes after end of anaesthesia, the core temperature was significantly higher for the warmed group: MD 0.60°C (95% CI 0.12, 1.08) for a control group temperature of 36.6°C. The confidence interval is fairly wide (Figure 14).

Figure 14: Core temperature; warmed inspired gas versus usual care; with thermal insulation in both groups
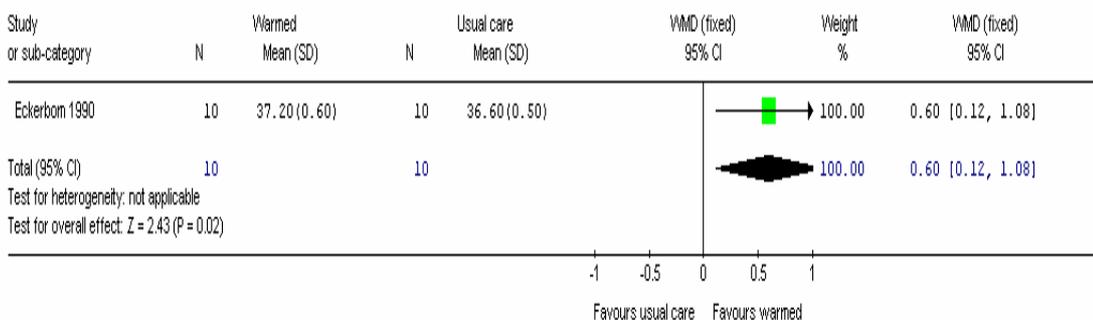
1 **10.7 PHARMACOLOGICAL AGENTS FOR THE PREVENTION OF IPH**

2

3 **SEARCH STRATEGY FOR IDENTIFICATION OF STUDIES**

4 Searches were performed on the following core databases: MEDLINE, EMBASE, CINAHL and

5 *The Cochrane Library* (1966 to current day with guidance from the GDG). Additional

6 databases were not searched for this review. The search strategies are given in Appendix B.

7

8 The titles and abstracts from the search strategy were assessed. Thirty-one were identified to

9 be potentially relevant to the review and these papers were retrieved in full. Eleven studies

10 met the inclusion criteria for the review. The reference lists of the retrieved studies were

11 inspected for further potential papers, but none were identified. The 20 excluded studies are

12 listed in Appendix E, along with reasons for exclusion.

13

14 **DESCRIPTION OF STUDIES INCLUDED IN THE REVIEW**

15 Eleven studies met the inclusion criteria for the review (Ikeda 1999; Mizobe 2006; Mohamed

16 2005; Piper 2000; Piper 2001; Sahin 2002; Selldén 1994; Selldén 1996; Selldén 1999;

17 Umenai 2006; Widman 2002). No studies were conducted in the UK; seven were conducted in

18 the rest of Europe, three in Japan and one in Egypt. Four studies had more than two arms,

19 giving a total of 27 comparisons. The Selldén (1999) study was a further report of patients

20 from both the Selldén (1994) and (1996) studies, reporting hospital stay. Results were not

21 given separately for the 1994 and 1996 studies and the amino acids groups from both earlier

22 studies were combined, giving 18% non-randomised patients. Thus, there were only ten

23 primary studies and 27 comparisons.

24

25 Seven studies had 50 patients or fewer in each comparison (Ikeda 1999; Mizobe 2006;

26 Mohamed 2005; Sahin 2002; Selldén 1994; Selldén 1996; Widman 2002), two of which had

27 fewer than 20 patients (Ikeda 1999; Selldén 1996). Three studies had more than 100 patients

28 in total: Piper (2000) had 30 patients in each of four arms; Piper (2001) had 30 patients in

29 each of five arms, and; Umenai (2006) had 68 and 66 patients in the two arms.

30

31 **Population and details of surgery and anaesthesia**

32 The mean age (where given) ranged across the studies from 32 to 68 years.

33

34 Surgery was carried out under general anaesthesia in all the studies except Widman (2002).

35 The duration of anaesthesia was more than 1 hour in eight studies (Mohamed 2005; Piper

36 2000; Piper 2001; Sahin 2002; Selldén 1994; Selldén 1996; Umenai 2006; Widman 2002) and

37 not stated in the other two (Ikeda 1999; Mizobe 2006).

38

39 The types of surgery in the studies were gynaecological (Selldén 1996); neurosurgical (Sahin

40 2002); abdominal (Mizobe 2006; Mohamed 2005; Selldén 1994); cardiothoracic (Umenai

2006); oral (Ikeda 1999); orthopaedic (Widman 2002); mixed (Piper 2000; Piper 2001; Selldén 1999). Surgery lasted 1 to 3 hours in six studies (Ikeda 1999; Piper 2000; Piper 2001; Selldén 1994; Selldén 1996; Widman 2002); over 3 hours in three studies (Mohamed 2005; Sahin 2002; Umenai 2006) and was not stated in one study (Mizobe 2006).

Two studies recorded tympanic temperatures, five rectal, three oesophageal, while one recorded mixed venous blood temperature using a cannula in the pulmonary artery.

Interventions

The following interventions were assessed:

- Alpha adrenergic agonists: phenylephrine, one study (Ikeda 1999);
- Alpha$_1$-adrenergic antagonists: urapidil, two studies (Piper 2000; Piper 2001);
- Amino acids: six studies:
  - One study gave Aminosteril KE 10% at 125ml/h, corresponding to 240kJ/h (Mohamed 2005);
  - One study gave Traumamine at 100kJ/h (Sahin 2002);
  - Three studies gave Vamin 18gN/l at126 ml/h, corresponding to 240 kJ/h (Selldén 1994; Selldén 1996; Widman 2002);
  - One study gave Teruamino 18g N/l at 2ml/kg/h, corresponding to 4kJ/kg/h (Umenai 2006);
- Sugars: fructose, one study (Mizobe 2006).

Ikeda (1999) and Mohamed (2005) used warmed intravenous fluids for all the patients. In two studies some patients had warmed blood:

- In Selldén (1994), all patients except one were undergoing minor surgery and received no active warming; 1 patient (in the amino acid group) received 4 units of warmed blood.
- In Selldén (1996), all patients except one received no active warming; 1 patient (in the control group) received 1 unit of warmed blood.

In the other studies, patients received no active warming.

Comparisons

The interventions were subdivided into preoperative, intraoperative, or postoperative phases, or a combination of phases. The included studies covered the following comparisons:

- **Preoperative phase**

  Intervention versus placebo / no intervention:
  - Amino acids solution versus saline (Selldén 1996b).

- **Intraoperative phase**

  Intervention versus placebo / no intervention:
  - Phenylephrine versus no intervention (Ikeda 1999);

- o Urapidil versus placebo (Piper 2000, Piper 2001);
- o Amino acids solution versus saline (Selldén 1994).

Intervention 1 + intervention 2 versus intervention 2 alone:

- o Amino acid solution plus isoflurane anaesthesia versus isoflurane anaesthesia alone (Sahin 2002);
- o Amino acids solution plus propofol anaesthesia versus propofol anaesthesia alone (Sahin 2002).

Intervention drug class 1 versus class 2:

- o Urapidil versus clonidine (Piper 2000; Piper 2001).

- **Pre and intraoperative phases**

Intervention versus placebo / no intervention:

- o Amino acids solution versus placebo (Selldén 1996a; Selldén 1999);
- o Amino acids solution versus placebo: both groups had circulating water mattress at 37°C (Umenai 2006);
- o Amino acids solution plus saline as needed versus saline as needed (Mohamed 2005);
- o Fructose infusion versus placebo (Mizobe 2006).

Spinal Anaesthesia:

- o Amino acids solution versus acetated Ringer's solution (Widman 2002).

The Selldén (1999) study was an amalgamation of Selldén (1994) and Selldén (1996), with all amino acids groups combined. Thus, some patients had infusions in the preoperative phase only, some intraoperative only and some in both phases.

Cross-phase comparison

- **Pre and intraoperative versus preoperative**
  - o Amino acids solution given 1 hour before + 1 hour during anaesthesia versus amino acids solution given 2 hours before anaesthesia (Selldén 1996c).

METHODOLOGICAL QUALITY

The quality assessment for the included trials is shown in Appendix D. The method of randomisation was reported in four studies, three of which were classified as adequate (computer generated: Ikeda 1999; Mizobe 2006; Umenai 2006). The exception was a quasi-randomised trial (Selldén 1994) in which patients were allocated alternately to treatment or control.

A further trial, Selldén (1996), randomised two groups of patients to receive either amino acids (1 hour before and 1 hour during anaesthesia) or saline control. The study also included a further group of patients, added later but not randomised, who had amino acids for 2 hours prior to anaesthesia. Thus the comparison of this group with either saline or the pre and intra

1 operative infusion was not randomised, and open to bias. The other studies did not state the
2 method of randomisation.
3
4 Partial allocation concealment (sealed envelopes) was reported in three studies (Mizobe 2006;
5 Umenai 2006; Widman 2002). One study reported what was assumed to be inadequate
6 allocation concealment: Selldén (1994) stated that patients were allocated alternately to
7 treatment or control. Allocation concealment was not reported in the other studies.
8
9 Eight studies reported that the outcome assessors and the patients were blinded to the
10 interventions, although Ikeda (1999) was reported as single-blind. Blinding was not stated in
11 Mohamed (2005); one study (Selldén 1996) was not blinded.
12
13 Four studies (Piper 2000; Piper 2001; Umenai 2006; Widman 2002) described an *a-priori*
14 power calculation. These calculations suggested that the sample size should be 30 patients
15 per group (Piper 2000); 27 (Piper 2001); 65 (Umenai 2006) and 30 (Widman 2002).
16
17 All studies used an intention to treat analysis. Only one study (Umenai 2006) reported loss to
18 follow up: 26% of patients [14/68 (20%) in the saline group and 21/67 (31%) in the amino acid
19 group] had their operations converted during the procedure, after they had received the study
20 interventions, so they no longer met the inclusion criteria for the study. The authors then
21 randomised a further 45 patients in a ratio of 2:3 to replace the lost patients. 4/18 and 7/27 of
22 these were withdrawn from the saline and amino acids groups respectively. There was no
23 significant difference in the baseline characteristics of the remaining patients. We decided to
24 treat this study with slight reservation.
25
26 All studies included in the review demonstrated baseline comparability of the groups on
27 characteristics such as age, gender, duration of surgery and ambient air temperature. The
28 comparability of baseline core temperatures is shown in Figure 1. Piper (2000) and Piper
29 (2001) did not report baseline core temperatures in the groups before the intervention. The
30 Selldén (1996c) comparison showed a significant difference in baseline core temperature of
31 0.4°C; Widman (2002) reported a significant difference in baseline temperature of -0.30°C,
32 and Mohamed (2005) reported a borderline difference of 0.10°C (p=0.05). Otherwise there
33 were no baseline differences. Both of these studies were regarded with caution, especially if
34 the effect size was not more than 5 times the baseline difference.
35
36 **Figure 1: Baseline core temperatures**

Review:	Inadvertent perioperative hypothermia
Comparison:	10 Baseline core temperatures
Outcome:	02 Baseline core temperatures

Study or sub-category	N	Treatment Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Ikeda 1999	9	37.40(0.30)	9	37.30(0.30)		3.13	0.10 [-0.18, 0.38]
Mizobe 2006	20	36.80(0.30)	20	36.70(0.30)		9.64	0.10 [-0.06, 0.26]
Mohamed 2005	20	37.10(0.20)	20	37.00(0.10)		25.07	0.10 [0.00, 0.20]
Sahin a	10	36.97(0.40)	10	36.70(0.21)		3.07	0.27 [-0.01, 0.55]
Sahin b	10	36.70(0.44)	10	36.90(0.56)		1.24	-0.20 [-0.64, 0.24]
Sellden 1994	10	36.60(0.10)	11	36.60(0.10)		32.84	0.00 [-0.09, 0.09]
Sellden 1996 a	8	37.09(0.14)	8	36.98(0.40)		2.79	0.11 [-0.18, 0.40]
Sellden 1996 b	8	36.69(0.28)	8	36.98(0.40)		2.10	-0.29 [-0.63, 0.05]
Sellden 1996 c	8	37.09(0.14)	8	36.69(0.28)		5.12	0.40 [0.18, 0.62]
Sellden 1999	45	36.80(0.67)	30	36.80(0.55)		3.13	0.00 [-0.28, 0.28]
Umenai 2006	66	36.30(0.62)	68	36.10(0.84)		3.87	0.20 [-0.05, 0.45]
Widman 2002	22	36.60(0.30)	24	36.90(0.30)		7.99	-0.30 [-0.47, -0.13]

-1 -0.5 0 0.5 1
Favours treatment   Favours control

Six studies were considered to have potential for bias (Mohamed 2005; Selldén 1994; Selldén 1996; Selldén 1999; Widman 2002; Umenai 2006). One study (Selldén 1994) was considered to be at higher risk because the patients were allocated alternately to treatment or control, and this was investigated in sensitivity analyses. Two further studies (Widman 2002; Mohamed 2005) were considered with caution because of differences in baseline temperatures. Another study had a slightly higher potential for bias: Umenai (2006) because of the drop-out rate, and this study was treated with caution. Selldén (1996) had two comparisons that were not randomised and these were not considered with the randomised studies; the Selldén (1996c) comparison also had a large baseline difference (0.4°C).

As mentioned earlier, the Selldén (1999) study was a combination of Selldén (1996) and (1994) and included 18% non-randomised patients. The component studies also had different methods of sequence generation and consequently this study was treated as having potential for bias.

RESULTS

I. Preoperative phase

A. Pharmacological agent versus placebo / no intervention

A1. Amino acids

Selldén (1996b) measured the change in temperature in 16 patients, for a solution of amino acids versus saline infused for 2 hours prior to anaesthesia (duration 128 (SEM 13) minutes for the amino acids group versus 154 (SEM 11) minutes for controls; not a significant difference). The theatre temperature was 21 to 23ºC; patients received no warming except for one patient in the control group who had 1 unit of warmed blood.

1. Core temperatures postoperatively

Core temperatures were measured at baseline, after one hour of infusion (i.e. preoperatively) and postoperatively on awakening. There was a fairly large, statistically significant difference in core temperature postoperatively. The amino acids group was warmer, with a mean difference of 0.51°C (95% CI 0.14, 0.88), for a control group mean temperature of 35.98°C, i.e. the control group was only just hypothermic. We note that the patients were not randomised to treatments for this comparison and that the postoperative temperatures were

1 measured at different times for the two groups. Therefore, this study was considered to be
2 biased.
3
4 **Figure 2: Core temperature**

5
6
7 **II. Intraoperative phase**
8 **A. Pharmacological agent versus placebo / no intervention**
9 **A1. Alpha adrenergic agonists (e.g. phenylephrine)**
10 One study (Ikeda 1999) compared phenylephrine 0.5μg/kg/min infusion from the start of
11 anaesthesia versus no treatment in 18 patients. IV fluids were warmed to 37ºC; the theatre
12 temperature was 25 to 26ºC; patients were covered with single cotton blanket and surgical
13 drape. We note that this study changed two variables at once and effectively had two
14 simultaneous warming interventions, warmed fluids and phenylephrine.
15
16 **1. Core temperature at various intraoperative times**
17 Mean core temperatures were significantly higher in patients given warmed phenylephrine at
18 15, 30, 45 and 60 minutes and at the end of surgery (mean duration of surgery 125 minutes
19 (SD 92) in the control group; 143 (SD 42) minutes in the phenylephrine group; not significantly
20 different), as shown in Figure 3. The confidence intervals are fairly wide.
21
22 **Figure 3: Core temperature**

Review: Inadvertent perioperative hypothermia
Comparison: 11 Prevention studies
Outcome: 16 Intra-operative phenylephrine vs. placebo
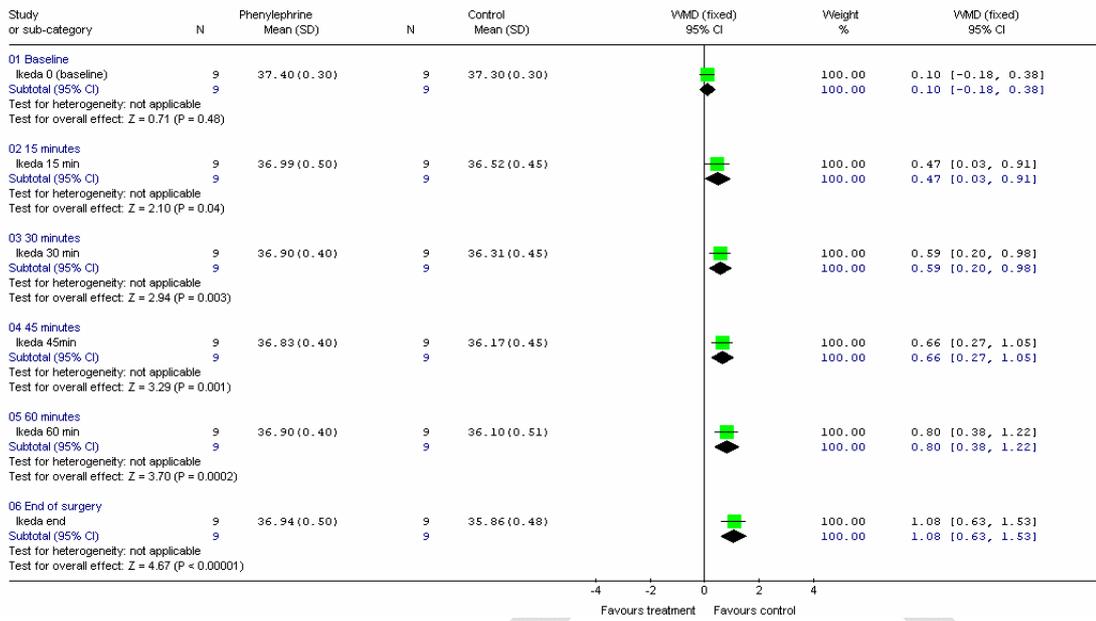
NB: Scale -4 to +4

A2. Alpha$_1$ - adrenergic antagonist

Two studies (Piper 2000; Piper 2001) compared urapidil given IV at the end of surgery versus placebo in 120 patients. Piper (2000) used a dose of 0.2mg/kg and Piper (2001) randomised the patients to three doses: 0.2mg/kg [a], 0.3mg/kg [b], or 0.4mg/kg [c] and placebo. Patients were covered with a cotton sheet. The outcomes were core temperatures 15 and 60 minutes after extubation, the extubation time and the time in the recovery room.

1. Core temperature 15 and 60 minutes after extubation

Figure 4 shows the effect of urapidil; this is reported as single comparisons, by dose, and as meta-analyses across all doses. There was no significant difference between interventions, although the 0.3mg/kg dose was almost significant in comparison with placebo, with the urapidil group being warmer by 0.2°C (95% CI -0.01, 0.41; p=0.06). There was no heterogeneity in the meta-analyses.

Figure 4: Core temperature post extubation
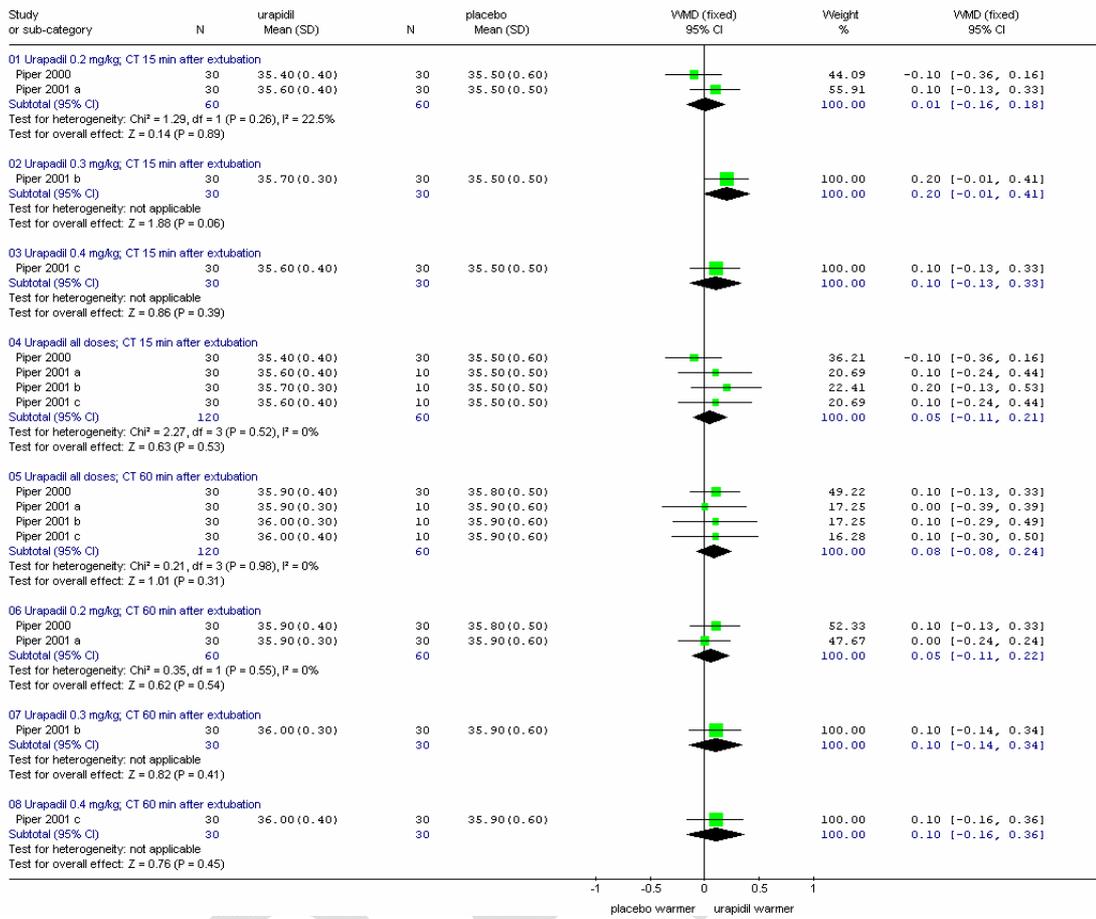
2. Time to extubation

There was no significant difference between groups for the time to extubation at any dose or in the meta-analysis of all three doses. There was no heterogeneity in the meta-analysis.

Figure 5: Time to extubation
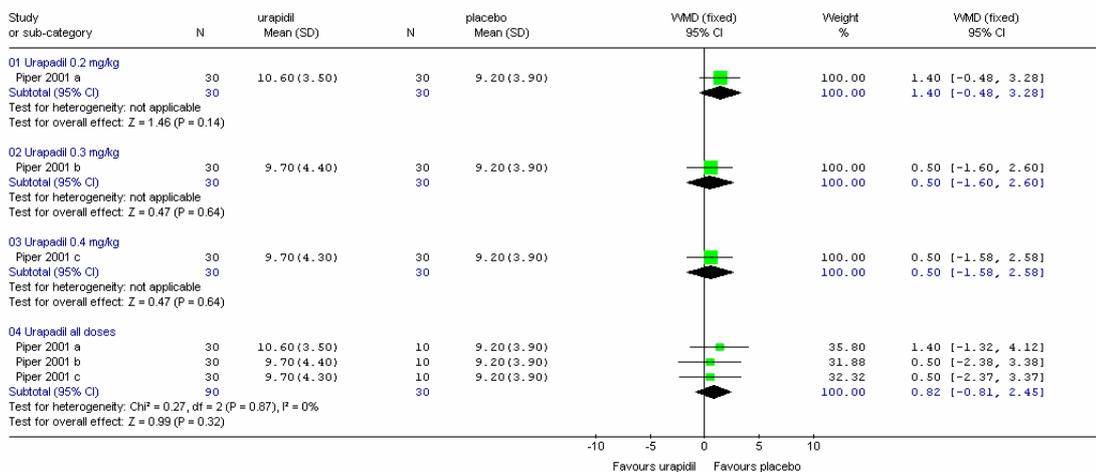
3. Time in PACU

The mean duration of surgery was 87.5 (SD 43.5) minutes in Piper (2000), and in the Piper (2001) study, 88.0 (SD 40.1) minutes for the 0.2mg/kg dose, 77.8 (SD 43.5) for the 0.3mg/kg dose, and 84.7 (SD 46.0) for the 0.4mg/kg dose. There was no significant difference between interventions in the time spent in PACU for any dose. The meta-analysis showed no heterogeneity.

Figure 6: Time in PACU
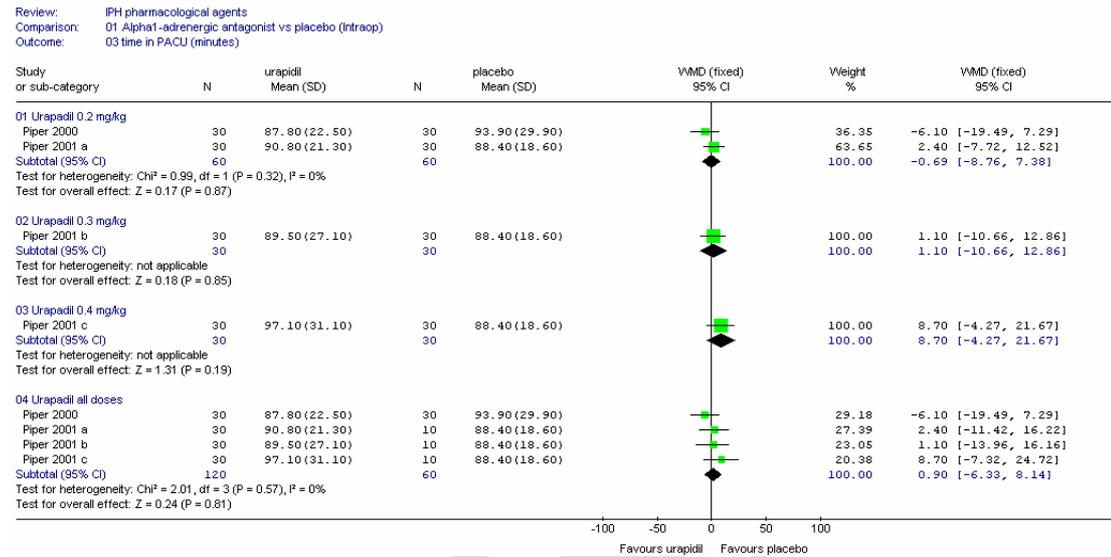
A3. Amino acids

Two studies (three comparisons) investigated the effect of amino acids versus placebo or no intervention:

- Sahin (2002) compared an amino acid solution plus isoflurane anaesthesia (group 1) versus isoflurane anaesthesia alone (group 2) (Sahin 2002a), and in the same study, compared an amino acid solution plus propofol anaesthesia (group 3) versus propofol anaesthesia alone (group 4) (Sahin 2002b). All patients received dextrose-free crystalloids and colloids at room temperature; the theatre temperature was 21ºC (SD 1). At the end of surgery, patients with temperatures below 35ºC were warmed by a forced air warming device in PACU before extubation. We note that there was no placebo infusion, so that room temperature infusion may have led to some cooling, thus underestimating the size of the effect.

- Selldén (1994) compared an amino acids solution versus saline control; the theatre temperature was 21 to 23ºC; there was no warming except for one patient with a partial gastrectomy in the amino acids group (major surgery) who had 4 units of warmed blood. The core temperature was measured using mixed venous blood from the pulmonary artery. We note that the Selldén (1994) study was quasi randomised.

1. Core temperature intraoperatively

1   Meta-analysis of the two Sahin studies (n=40) showed no significant difference
2   intraoperatively between groups up to 3 hours. The mean duration of surgery was 268.5 (SD
3   139.7) minutes for the isoflurane only group; 270.5 (SD 104.6) minutes for the propofol only
4   group; 356.0 (SD 136.1) minutes for the isoflurane plus amino acid group and 242.0 (SD 92.6)
5   minutes for the propofol plus amino acid group.

6

7   The Selldén (1994) study, in 21 patients, however, showed a significant difference at 90
8   minutes, which does not align with the Sahin results. The Selldén (1994) study is possibly
9   biased by the alternate allocation used, however, we note that there may have been a cooling
10   effect in the intervention group of the Sahin (2002) study because of the infusion of room
11   temperature fluids.

12

13   At the end of surgery, meta-analysis showed a significantly higher mean core temperature for
14   the intervention group, but in the absence of the Selldén (1994) study, the meta-analysis was
15   not significant; WMD 0.76°C (95% CI -0.08, 1.60).

16

17   **Figure 7: Core temperature**

18
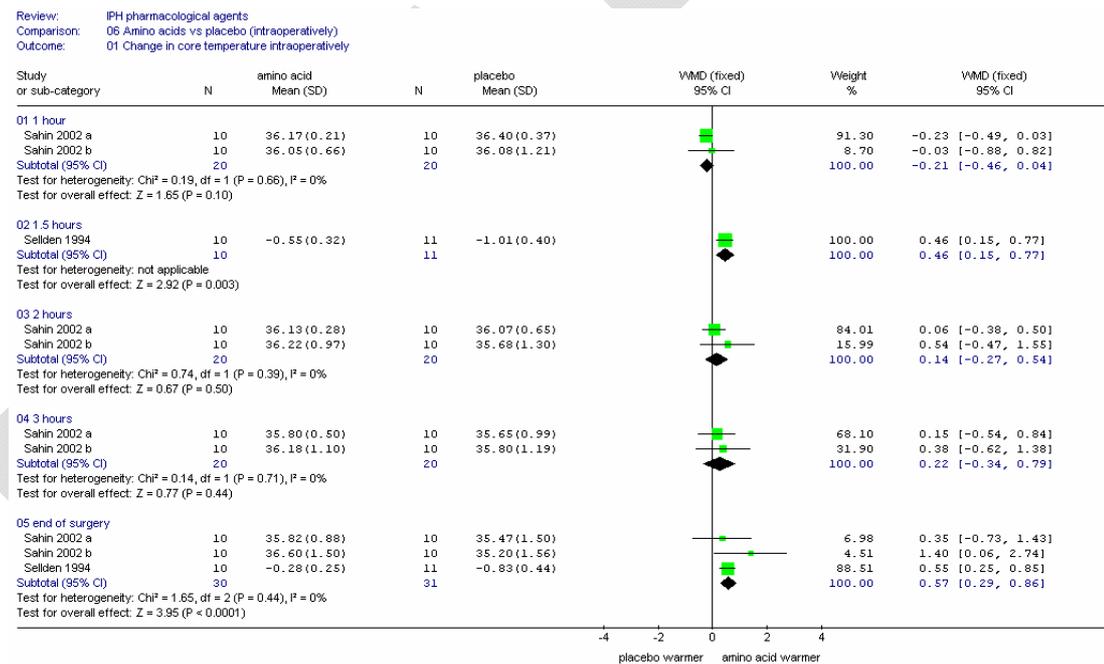
19   NB: Scale -4 to +4

20

21   **III. Pre and intraoperative phases**
22   **A. Pharmacological agent versus placebo / no intervention**
23   Six studies compared the effect of pharmacological agents in the pre and intraoperative
24   phases (Mohamed 2005; Mizobe 2006; Selldén 1996a; Selldén 1999; Umenai 2006; Widman
25   2002). In Umenai (2006), both groups had circulating water mattress at 37°C. In Mohamed
26   (2005), the patients had amino acids solution plus saline as needed versus saline as needed.
27   The Widman (2002) study gave the patients spinal anaesthesia and was treated separately.

We note that the Selldén (1996a) comparison was randomised (and therefore acceptable) and that the Umenai (2006) study had some loss to follow-up. The Selldén (1999) study was a partially randomised, and was an amalgamation of Selldén (1994) and Selldén (1996), with all amino acids groups combined. Thus, some patients had infusions in the preoperative phase only, some intraoperative only and some in both phases.

A1. Amino acids

GENERAL ANAESTHESIA

Mohamed (2005), Selldén (1996a), Selldén (1999) and Umenai (2006) studied amino acids given both pre and intraoperatively. The outcomes measured were:

- Preoperative temperature (Selldén 1996a; after 1 hour of infusion; theatre temperature 21 to 23ºC; patients received no warming except for one patient in the control group who had 1 unit of warmed blood);
- Preoperative temperature (Mohamed 2005) after 30 and 60 minutes of infusion, warmed to 37°C;
- Ontraoperative temperatures (Mohamed 2005: 30, 60, 120 and 180 minutes; infusion warmed to 37°C);
- Temperature at the end of surgery (Umenai 2006: mean duration of surgery 5.5 hours [95% CI 5.2, 5.7] for amino acid group versus 5.1 hours [95% CI 4.8, 5.5] for saline group; difference just non-significant; theatre temperature near 23ºC; covered with one layer sheet during surgery; circulating water mattress under patients set to 37ºC);
- Postoperative temperatures (Selldén 1996a: on awakening at the end of anaesthesia, and; Mohamed 2005: 30 minutes postoperatively);
- Duration of hospitalisation (Selldén 1999: theatre temperature 20 to 23ºC; no warming except for five patients who had warmed blood; this report includes the patients in Selldén 1994 and Selldén 1996).

1. Intraoperative temperatures

One study (Mohamed 2005) recorded the core temperature at various times intraoperatively in 40 patients for an amino acid solution (given 1 hour before induction and 1 hour after) versus no infusion. Both groups were also given IV nutrient-free saline according to the fluid requirements of the patient and all IV infusions were given at 37ºC. Thus, this study gave two interventions at once: the amino acids and warmed fluids, which were not compared with placebo. For this study there was a statistically significant difference at all times up to and including 3 hours. We note that the control group temperature did not drop below 36.0°C until 2 hours.

Umenai (2006) studied 134 patients and compared an infusion of amino acids, started 2 hours before induction of anaesthesia and continued for 6 hours, versus an infusion of saline for the

1   same length of time. Umenai (2006) reported that core temperatures became significantly

2   higher in the amino acid group than in the saline group from 150 minutes after induction of

3   anaesthesia until the end of surgery (p=0.005).

4

5   These studies were combined in a meta-analysis, but there was significant heterogeneity,

6   possibly explained by the different interventions (warmed amino acids in Mohammed 2005

7   and unwarmed amino acids in Umenai 2006) combined with the different comparators (no

8   placebo in Mohammed 2005; and placebo infusion in Umenai 2006).

9

10   For the economic analyses it was decided to use the Umenai (2006) results, which may have

11   been a conservative estimate.

12

13   **Figure 8: Core temperature**

Review: Inadvertent perioperative hypothermia (Version wk1)
Comparison: 12 Other studies
Outcome: 79 Pre-op and intra-op amino acids versus placebo (temp)

Study or sub-category	N	Amino acids Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 30 min into intraop phase							
Mohamed 2005	20	37.10(0.10)	20	36.50(0.10)		100.00	0.60 [0.54, 0.66]
Subtotal (95% CI)	20		20			100.00	0.60 [0.54, 0.66]

Test for heterogeneity: not applicable
Test for overall effect: Z = 18.97 (P < 0.00001)

04 60 minutes into intraop phase							
Umenai 2006	66	35.83(0.83)	68	35.50(1.26)		6.89	0.33 [-0.03, 0.69]
Mohammed 2005	20	37.00(0.20)	20	36.10(0.10)		93.11	0.90 [0.80, 1.00]
Subtotal (95% CI)	86		88			100.00	0.86 [0.77, 0.96]

Test for heterogeneity: Chi² = 8.95, df = 1 (P = 0.003), I² = 88.8%
Test for overall effect: Z = 17.84 (P < 0.00001)

05 120 minutes into intraop phase							
Umenai 2006	66	35.40(0.83)	68	35.04(1.26)		16.14	0.36 [0.00, 0.72]
Mohammed 2005	20	36.90(0.30)	20	35.80(0.20)		83.86	1.10 [0.94, 1.26]
Subtotal (95% CI)	86		88			100.00	0.98 [0.84, 1.13]

Test for heterogeneity: Chi² = 13.59, df = 1 (P = 0.0002), I² = 92.6%
Test for overall effect: Z = 13.28 (P < 0.00001)

-4   -2   0   2   4
Favours control   Favours amino acids

14

15   NB: Scale -4 to +4

16

17   **2. Temperature at the end of surgery**

18   Umenai (2006) reported that, at the end of surgery, there was a significantly higher mean

19   temperature for the amino acids group: MD 0.50 (95% CI 0.18, 0.82). The confidence interval

20   is fairly wide, and there was some loss to follow-up.

21

22   **Figure 9: Core temperature at end of surgery**

Review: Inadvertent perioperative hypothermia
Comparison: 11 Prevention studies
Outcome: 22 Pre- + intra-operative amino acids versus placebo (end of surgery)

Study or sub-category	N	Amino acid Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Umenai 2006	66	36.10(0.83)	68	35.60(1.05)		100.00	0.50 [0.18, 0.82]
Total (95% CI)	66		68			100.00	0.50 [0.18, 0.82]

Test for heterogeneity: not applicable
Test for overall effect: Z = 3.06 (P = 0.002)

-1   -0.5   0   0.5   1
Favours control   Favours amino acid

23

24

25   **3. Postoperative temperatures**

26   Two studies recorded postoperative core temperatures: Selldén (1996a) recorded the change

27   in temperature at awakening in 16 patients; Mohamed (2005) gave the temperatures at 30

1 minutes postoperatively in 40 patients. For Selldén (1996a) there was a large statistically
2 significant difference postoperatively: MD 1.16 (95% CI 0.58, 1.74) for a control group
3 temperature of 35.98°C (i.e. the control group was only just hypothermic); the confidence
4 interval is wide, however. Mohamed (2005) showed a significant difference, 30 minutes post
5 extubation, of 0.60 (95% CI 0.41, 0.79) for a control group temperature of 36.40ºC, i.e. not
6 hypothermic).

7

8 **Figure 10: Core temperature postoperatively**

Review: Inadvertent perioperative hypothermia
Comparison: 11 Prevention studies
Outcome: 21 Pre- + intra-operative amino acids versus placebo (post-op temp)

Study or sub-category	N	Amino acid Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 On awakening							
Sellden 1996 a post	8	37.14(0.76)	8	35.98(0.34)		100.00	1.16 [0.58, 1.74]
Subtotal (95% CI)	8		8			100.00	1.16 [0.58, 1.74]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 3.94 (P < 0.0001)							
02 30 min postoperatively							
Mohamed postop 30 mn	20	37.00(0.30)	20	36.40(0.30)		100.00	0.60 [0.41, 0.79]
Subtotal (95% CI)	20		20			100.00	0.60 [0.41, 0.79]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 6.32 (P < 0.00001)							

-4   -2   0   2   4
Favours control   Favours amino acid

9

10 NB: Scale -4 to +4

11

12 **4. Time in ICU**
13 One study (Umenai 2006) in 134 patients undergoing off pump CABG operations, recorded
14 the time spent in ICU, given as median values. The intervention and control groups were in
15 ICU for respectively 20 hours (95% CI 19.5, 38.4) versus 44 (95% CI 21, 45) hours. This was
16 a statistically significant difference (p=0.001). However, we note that there were some drop
17 outs in this study.

18

19 **5. Duration of hospital stay**
20 Umenai (2006) reported that there was a significant difference (p=0.004) in the median length
21 of stay in hospital for patients undergoing off pump CABG operations: amino acid group stay
22 was 10 days (95% CI 9, 11) and the control group was 12 days (95% CI 11, 13).

23

24 Selldén (1999) reported the duration of hospital stay for 75 patients treated across two studies
25 with amino acids or saline. This was significantly longer (MD 1.80 days [95%CI 0.26, 3.34]) for
26 the control group, favouring the amino acids. We note that this study had poor methodological
27 quality and had a mixture of protocols across different phases. The results are considered very
28 cautiously.

29

30 **SPINAL ANAESTHESIA**
31 The study using spinal anaesthesia (Widman 2002) assessed amino acids for 1 hour prior to
32 and during hip arthroplasty. The outcomes were temperature at start of operation (i.e. after 1
33 hour of infusion) and at the end of surgery (120 minutes for the amino acid group and 135
34 minutes, reported as not significantly different, in the control group).

1. Change in temperature at the end of surgery

For this study, the difference in temperature at baseline was significant (+0.3ºC). The difference in effect size was not five times greater than the baseline difference, so these results were considered to be flawed.

Figure 11: Change in temperature at the end of surgery

Review: Inadvertent perioperative hypothermia
Comparison: 13 Spinal anaesthesia
Outcome: 02 Change in temp by end of surgery

Study or sub-category	N	Amino acid Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
Widman 2002	22	-0.40(0.30)	24	-0.90(0.40)		100.00	0.50 [0.30, 0.70]
Total (95% CI)	22		24			100.00	0.50 [0.30, 0.70]

Test for heterogeneity: not applicable
Test for overall effect: Z = 4.82 (P < 0.00001)

-1 -0.5 0 0.5 1
Favours control   Favours amino acid

A2. Sugars

GENERAL ANAESTHESIA

Mizobe (2006) compared a fructose infusion (0.5 g/kg/h; not stated to be warmed) with a saline infusion, starting 3 hours before surgery and continuing for a further hour after induction, in 40 patients, but core temperatures were measured in only 20 of these (random selection). The theatre temperature was 24ºC; patients were covered with a cotton sheet preoperatively and with drapes during surgery.

1. Core temperatures

The core (oesophageal) temperature was measured at various intraoperative times. The temperature was significantly higher in the fructose group at all times. At 3 hours after induction of anaesthesia (i.e. 2 hours after the end of the infusions), the values were given in the text (not extracted from a graph) and for this time the mean difference was 0.60°C (95%CI 0.25, 0.95). The confidence interval is fairly wide.

Figure 12: Core temperature

Review: Inadvertent perioperative hypothermia
Comparison: 11 Prevention studies
Outcome: 01 Pre and intra-operative fructose vs placebo over time

Study or sub-category	N	Fructose Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 20 min from graph							
Mizobe 2006	10	36.55(0.21)	10	36.30(0.34)		100.00	0.25 [0.00, 0.50]
Subtotal (95% CI)	10		10			100.00	0.25 [0.00, 0.50]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 1.98 (P = 0.05)							
02 60 min from graph							
Mizobe 2006	10	36.21(0.21)	10	35.70(0.34)		100.00	0.51 [0.26, 0.76]
Subtotal (95% CI)	10		10			100.00	0.51 [0.26, 0.76]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 4.04 (P < 0.0001)							
03 120 min from graph							
Mizobe 2006	10	35.91(0.30)	10	35.27(0.39)		100.00	0.64 [0.34, 0.94]
Subtotal (95% CI)	10		10			100.00	0.64 [0.34, 0.94]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 4.11 (P < 0.0001)							
04 final temp (180 min) from text							
Mizobe 2006	10	35.70(0.40)	10	35.10(0.40)		100.00	0.60 [0.25, 0.95]
Subtotal (95% CI)	10		10			100.00	0.60 [0.25, 0.95]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 3.35 (P = 0.0008)							

-1 -0.5 0 0.5 1
Favours control   Favours fructose

2. Blood loss

Mizobe (2006) reported intraoperative blood loss in 20 patients. There was no significant difference between interventions, but the confidence interval is wide.

Figure 13: Intraoperative blood loss

Review: Inadvertent perioperative hypothermia
Comparison: 11 Prevention studies
Outcome: 23 Pre and intra-operative fructose vs placebo over time

Study or sub-category	N	Fructose Mean (SD)	N	Control Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 blood loss intraoperatively							
Mizobe 2006	10	275.00(93.00)	10	238.00(79.00)		100.00	37.00 [-38.63, 112.63]
Subtotal (95% CI)	10		10			100.00	37.00 [-38.63, 112.63]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 0.96 (P = 0.34)							

-100   -50   0   50   100
Favours fructose   Favours control

IV. Cross-phase comparison

A1. Amino acids

Selldén (1996c) compared the effect in 16 patients of an amino acid solution given 1 hour before and 1 hour during anaesthesia versus an amino acid solution given two hours before general anaesthesia. We note that this comparison had one non-randomised group and is thus equivalent to a non-randomised study, and that there was a large baseline difference in core temperature (0.4°C), which was comparable with the effect size. Consequently, the study is and results are not given.

1 **11 TREATMENT**

2

Clinical Question: Are warming devices/mechanisms effective in treating IPH in adults in the different phases of perioperative care?

3

4 **SELECTION CRITERIA**

5 Selection criteria were as outlined in the general methods section.

6

7 **Types of intervention**

8 The following interventions were to be considered:

9 1. Active warming mechanisms

10   The following types of warming mechanisms were considered under active warming:

11   a. Forced air warming

12   b. Electric blanket

13   c. Water mattress

14   d. Radiant heating

15   e. Warmed blankets

16   f. Heating gel pad.

17

18 2. Thermal insulation mechanisms

19   The following mechanisms were considered under thermal insulation:

20   a. Reflective blanket

21   b. Reflective clothing.

22

23 Other types of heat loss prevention, such as cotton sheets, cotton blankets, or wool blankets

24 were considered to be 'usual care', unless the blankets were actively warmed.

25

26 **Perioperative phase**

27 Treatment of hypothermia could take place in any of the perioperative phases, but the phases

28 were treated separately.

29

30 **Types of comparison**

31 The following comparisons were to be included:

32 1   Warming versus usual care

33 2   Active Warming Type 1 versus type 2

34 3   Active warming type 1 plus thermal insulation type 1 versus active warming type 2 plus

35   thermal insulation type 1

1   4   Thermal insulation type 1 versus type 2

2   5   Type 1 plus Type 2 versus type 1

3   6   Duration 1 versus duration 2

4   7   Temperature setting 1 versus setting 2

5   8   Active warming versus thermal insulation.

6

7   Subgroup analyses were planned by type of warming device, power, duration of warming and

8   degree of hypothermia.

9

10   **Characteristics of clinical studies included in the review (Appendix C)**

11   Eleven studies were included in this review (Alfonsi 2003; Bredahl 1995; Giuffre 1991;

12   Hershey 1997; Jackson 1997; Karayan 1996; Lennon 1990; Stevens 2000; Summers 1990;

13   Vanni 2003; Weyland 1994).

14

15   An additional study (Bräuer 2004) was included as indirect evidence, and is presented

16   separately. The indirect population comprised cardiac patients, in the post-bypass stage after

17   rewarming, who then underwent inadvertent hypothermia ('after drop').

18

19   The three studies excluded from the review are listed in Appendix E.

20

21   **Study details**

22   A total of 676 patients were included in the eleven studies. There were 50 additional patients

23   in the indirect study, Bräuer (2004). The total number of patients in each study ranged from 18

24   (Alfonsi 2003) to 144 (Hershey 1997). Eight studies had fewer than 20 patients in the

25   intervention arm (Alfonsi 2003; Bredahl 1995; Jackson 1997; Karayan 1996; Lennon 1990;

26   Vanni 2003; Weyland 1994; Bräuer 2004, indirect) and two of these had less than 20 patients

27   overall (Alfonsi 2003; Karayan 1996).

28

29   No studies were conducted in the UK, four studies were conducted in the US (Giuffre 1991;

30   Hershey 1997; Lennon 1990; Summers 1990); two studies in France (Alfonsi 2003; Karayan

31   1996); two in Germany (Weyland 1994; Bräuer 2004, indirect), and one each in Denmark

32   (Bredahl 1995); Brazil (Vanni 2003); South Africa (Jackson 1997) and Australia (Stevens

33   2000).

34

35   Mainly the studies did not state the source of funding (if any), but one (Summers 1990) was

36   part funded by grant from Augustine Medical (forced air warming device manufacturer).

37

38   Five studies had more than two randomised groups: Guiffre (1991) had three arms; Hershey

39   (1997) had three arms; Vanni (2003) had three arms; Weyland (1994) had three arms; Bräuer

40   (2004, indirect) had five arms. Overall there were 18 direct study comparisons and ten indirect

1   comparisons.

2

3   One study (Vanni 2003) treated the patients in the intraoperative phase or in both pre and

4   intraoperative phases. One study treated the patients in the intraoperative phase (Karayan

5   1996). The other nine studies investigated treatment of IPH in PACU or ICU.

6

7   **Participants**

8   The age of the patients ranged from 16 to 86 years with a mean age (where given) ranging

9   from 31 to 66 years; one study only included patients over 50 years (Bredahl 1995), and one

10   study excluded patients over 60 years (Hershey 1997). Two studies were carried out

11   exclusively in men (Alfonsi 2003; Bräuer 2004, indirect); one study was exclusively in women

12   (Vanni 2003). Two studies did not state the gender (Karayan 1996; Lennon 1990). BMI was

13   not stated in any study, although two (Alfonsi 2003; Karayan 1996) reported that none of the

14   patients were obese, and two studies (Weyland 1994; Bräuer 2004, indirect) stated that the

15   body weight was within -10% and +30% of normal.

16

17   Three studies included patients with ASA I to II status (Alfonsi 2003; Bredahl 1995; Vanni

18   2003); one studies had patients with ASA II to III (Karayan 1996) and one had patients with

19   ASA I to III (Weyland 1994). In the indirect study, Bräuer (2004), the patients were ASA III and

20   the other studies did not state the ASA status.

21

22   Generally, the studies gave insufficient information about the surgery and anaesthesia. Eight

23   studies reported the type of surgery:

24   • Alfonsi (2003) was orthopaedic;

25   • Vanni (2003) and Karayan (1996) were abdominal;

26   • Hershey (1997) was predominantly gynaecological;

27   • Bredahl (1995) was major thoracic, abdominal (mainly) and orthopaedic;

28   • Stevens (2000) was general, orthopaedic, urological, vascular and gynaecological;

29   • Weyland (1994) was major orthopaedic, gynaecological and urological;

30   • The indirect study was cardiothoracic.

31

32   The grade of surgery was classified only for two studies (Alfonsi 2003; Karayan 1996) and

33   was grade 2.

34

35   Five studies stated the surgery was elective (Bredahl 1995; Karayan 1996; Vanni 2003;

36   Weyland 1994; Bräuer 2004, indirect). Six studies stated the duration of surgery:

37   • Alfonsi (2003) was 87(SD 37) minutes;

38   • Bredahl (1995) was 165 (120 to 320) minutes;

39   • Hershey (1997) had mean durations of 184 and 233 minutes;

40   • Summers (1990) had 138 and 173 minutes;

- Vanni (2003) was 180 minutes;
- Karayan (1996) had 278 and 312 minutes;
- Stevens (2000) only included patients having operations lasting more than 20 minutes.

Patients had general anaesthesia in seven studies (Hershey 1997; Lennon 1990; Jackson 1997; Karayan 1996; Vanni 2003; Weyland 1994; Bräuer 2004, indirect); combined general and regional in two (Alfonsi 2003; Bredahl 1995), and a mixture of general and/or regional in one (Stevens 2000). Two studies did not mention the type of anaesthesia (Giuffre 1991; Summers 1990). Duration of anaesthesia was more than 60 minutes in six studies (Alfonsi 2003; Bredahl 1995; Giuffre 1991; Summers 1990; Vanni 2003; Bräuer 2004, indirect) and not stated in the rest.

Patients were included if they had hypothermia, as defined by the authors, however, the degree and definition of hypothermia varied, as did the phase in which it occurred and the means of measuring temperature.

Four studies recorded the core temperature at the tympanic membrane (Alfonsi 2003; Stevens 2000; Summers 1990; Vanni 2003); one recorded temperature at the pulmonary artery (Karayan 1996); two gave oesophageal temperatures (Weyland 1994; Bräuer 2004, indirect); two rectal (Bredahl 1995; Jackson 1997) and three oral (Giuffre 1991; Hershey 1997; Lennon 1990). The GDG regarded rectal and oral temperatures as only partially adequate measures of core temperature, except when sufficient detail was given for the measurement of oral temperatures and so these studies were included but regarded with caution. Hershey (1997) stated that the oral thermometer measurements correlated moderately well with tympanic temperatures in a previous study.

Two studies (Alfonsi 2003; Karayan 1996) described mild hypothermia (35.0 to 35.9°C); one (Guiffre1991) was moderate (34.0 to 34.9°C); two were mild and moderate (Stevens 2000 excluded patients less than 34.5°C and Vanni 2003 reported mean temperatures between 34.9 and 35.2°C) and the rest did not state explicitly.

In the Karayan (1996) study, patients in the intervention group received forced air warming when their intraoperative core temperature dropped below 36.0°C; in practice, this was two hours after induction. The Vanni (2003) study was not designed as a trial to treat IPH, rather the intention was to prevent IPH. However all groups were hypothermic before forced air warming started. The authors attributed this drop in temperature to the premedication (7.5mg midazolam IM, 30 minutes before admission to the theatre, at which time patients were randomised to treatments). The GDG was not wholly convinced by this explanation and noted that this dose and route of administration is not used in the UK. The other studies had inclusion criteria for patients having temperatures below 36.0°C.

1

2 The three studies measuring tympanic membrane temperatures included patients with
3 temperatures less than 36.0°C (Summers 1990; Stevens 2000 – implied inclusion) or had a
4 final intraoperative temperature of 35.1°C. The studies recording oesophageal temperatures
5 included patients with temperatures less than 35.5°C; those with rectal temperatures had to
6 be less than 35.5°C (Bredahl 1995) or 35.9°C (Jackson 1997). One of the studies measuring
7 oral temperatures required an inclusion temperature of 35°C or less (Guiffre 1991; no places
8 of decimal), another was less than 35.0°C (Lennon 1990) and Hershey (1997) had an entry
9 requirement of less than 36°C (no places of decimal).

10

11 Two studies had patients who were ventilated in ICU (Weyland 1994; Bräuer 2004, indirect);
12 one study had about 30% of the patients ventilated (Hershey 1997); two studies had no
13 patients ventilated (Alfonsi 2003; Lennon 1990 [exclusion criterion]). One other study stated
14 the patients were in ICU (Jackson 1997).

15

16 **Interventions**
17 There was a range of interventions used:
18 - Forced air warming device in nine studies, all had full body covering unless otherwise
19   stated:
20   - Bair Hugger® maximum setting, 43°C, (Alfonsi 2003; Karayan 1996 (upper body
21   only) and Stevens 2000 (both said to be 'high' setting); and Bräuer 2004, indirect);
22   - Warm Touch® 42°C to 46°C (Jackson 1997; Vanni 2003);
23   - Warm Touch® maximum setting (Bräuer 2004, indirect);
24   - Bair Hugger® at a setting of 57°C, which was said to be medium[#] (Giuffre 1991);
25   - Bair Hugger® at an unclear setting (Lennon 1990; Summers 1990 (coverage not
26   stated).
27 - Electric blanket (50W), used until the temperature reached 37°C (Weyland 1994)
28 - Radiant heaters in five comparisons:
29   - Aragona Thermal Ceilings CTC X overhead heater, power setting 1kW, with the
30   heater placed 75cm above the patient's chest (Weyland 1994; Bräuer 2004, indirect);
31   - Aragona Thermal Ceilings CTC X overhead heater, power setting 500W, about 60cm
32   above the chest (Bredahl 1995);
33   - Radiant heater with two radiant lights placed 71cm above the patient's skin (Guiffre
34   1991);
35   - Self-assembled combination of four halogen lamps (each 160W) placed 65cm above
36   the patient's body surface (indirect Bräuer 2004).
37 - Head covering in one study (Hershey 1997)
38   - Warmed, but not said to be changed in Hershey (1997).

39

[#] Presumably this was a misprint and should have read 37°C

1   The temperature settings and durations of warming were as follows:

2

3   The Vanni (2003) study gave the patients forced air warming either 60 minutes before

4   induction and during the intraoperative period, or intraoperatively only. Karayan (1996) gave

5   forced air warming intraoperatively, two hours after induction of anaesthesia. Most of the other

6   studies using forced air warming devices warmed the patients until they reached a specified

7   temperature, but Summers (1990) seemed to restrict the warming period to one hour, and the

8   durations for Lennon (1990) and Jackson (1997) were 90 minutes and three hours

9   respectively.

10

11   Mostly the duration of radiant heating was until a specified temperature was reached, but the

12   Bredahl (1995) study heated the patients for 2 hours and the power was decreased if the skin

13   temperature exceeded 37°C.

14

15   **Comparators**

16   Several studies used heated blankets as a comparator. Two (Guiffre 1991; Stevens 2000)

17   specified that the blankets were changed on a regular basis (e.g. every 15 minutes); one

18   changed the blankets as needed (Summers 1990) and the others did not state if the blankets

19   were changed (Hershey 1997; Lennon 1996). One study (Lennon 1996) stated that the

20   blankets were warmed to 37°C, one reported that the blankets were stored at 66 to 77°C

21   (Giuffre 1991) and the others did not report the temperature. The GDG noted that the

22   procedure of changing blankets was not carried out in the UK.

23

1 **Comparisons**

2 The following comparisons were reported:

3

4 **I. Intervention in the preoperative phase**

5 • Active warming (preoperatively) plus active warming (intraoperatively) versus active
6 warming (intraoperatively) (Vanni 2003) [cross-phase].

7

8 **II. Intervention in the pre and intraoperative phases**

9 • Active warming versus usual care (Vanni 2003).

10

11 **III. Intervention in the intraoperative phase**

12 • Active warming versus usual care (Karayan 1996; Vanni 2003).

13

14 **IV. Intervention in the postoperative phase**

15 • Active warming versus usual care (Alfonsi 2003; Jackson 1997; Weyland 1994;Bräuer
16 2004, indirect [4 comparisons]);

17 • Active warming 1 versus Active warming 2 (Lennon 1990; Summers 1990; Weyland 1994;
18 Bräuer 2004, indirect [6]);

19 • Active warming 1 + other warming mechanism versus active warming 2 + other warming
20 mechanism (Giuffre 1991 [3]; Stevens 2000);

21 • Active warming versus thermal insulation (Bredahl 1995);

22 • Thermal insulation + other warming mechanism versus other warming mechanism
23 (Hershey 1997 [2]);

24 • Thermal insulation 1+ other warming mechanism versus thermal insulation 2 + other
25 warming mechanism (Hershey 1997).

26

27 There were no studies that simply investigated a thermal insulation mechanism versus usual
28 care.

29

30 More specifically the comparisons were:

31 **I. Preoperative phase**

32 **A. Active warming versus usual care**

33 **A1. Active warming (preoperatively) plus active warming (intraoperatively) versus**
34 **active warming (intraoperatively) [cross-phase]**

35 • Forced air warming for 60 minutes pre-induction (pre) plus forced air warming (intra)
36 versus usual care (pre) + forced air warming (intra) (Vanni 2003)

37

38 **II. Pre and intraoperative phase**

39 **A. Active warming versus usual care**

1
2
3
    • Forced air warming (full body) versus usual care (cotton sheet), from 60 minutes pre-induction; all patients received room temperature fluids at 8 to 10ml/kg/h (Vanni 2003).

4 **III. Intraoperative phase**

5 **A. Active warming versus usual care**

6 • Forced air warming (full body) versus usual care (cotton sheet) from induction

7   o All patients received room temperature fluids at 8 to 10ml/kg/h (Vanni 2003).

8 • Forced air warming (upper body) versus usual care (warm cotton sheet) from when the

9   patients became hypothermic (2 hours after induction)

10   o All patients received warmed fluids, at a volume of 3.1 and 3.8 litre (Karayan 1996).

11

12 **IV. Postoperative phase**

13 **A. Active warming versus usual care**

14 • Forced air warming versus usual care (two direct and two indirect studies):

15   o Full body forced air warming blanket (Bair Hugger®, 43°C) versus cotton blanket

16   (Alfonsi 2003);

17   o Forced air warming blanket from neck down (Warm Touch®, 42 to 46°C) versus two

18   cotton blankets (Jackson 1997);

19   o Full body forced air warming blanket (Bair Hugger®, max setting) versus standard

20   polyester filled hospital blanket; insulation value 1.7 clo (Bräuer 2004, indirect);

21   o Full body forced air warming blanket (Warm Touch®, max setting) versus standard

22   polyester filled hospital blanket; insulation value 1.7 clo (Bräuer 2004, indirect).

23 • Radiant heater versus usual care

24   o Radiant heater (Aragona Thermal Ceilings; 1kW, 75cm from chest) versus standard

25   hospital blanket (Weyland 1994);

26   o Radiant heater (Aragona Thermal Ceilings; 1kW, 75cm from chest) versus standard

27   polyester filled hospital blanket; insulation value 1.7 clo (Bräuer 2004, indirect);

28   o Radiant heater (self assembled): 4 Hydrosun 500 halogen lamps (4x160W; 60cm from

29   chest) versus standard polyester filled hospital blanket; insulation value 1.7 clo

30   (Bräuer 2004, indirect).

31 • Electric heating blanket versus usual care (standard hospital blanket; Weyland 1994).

32

33 **B. Active warming 1 versus active warming 2**

34 **B1. Active warming 1 versus active warming 2 (with no additional warming)**

35 • Forced air warming blanket versus warmed blankets (three studies):

36   o Forced air warming blanket (Bair Hugger®; 43°C) versus cotton blankets warmed to

37   37°C; not stated if changed systematically (Lennon 1990);

38   o Forced air warming blanket (Bair Hugger®; no details) versus warmed blankets

39   changed as needed (temperature not stated) (Summers 1990).

40 • Radiant heater versus electric blanket (one study):

1   o   Radiant heater (Thermal Ceilings; 1kW; 75cm from chest) versus electric blanket
2   (50W, placed between two standard hospital blankets) (Weyland 1994)
3
4   **B2. Active warming 1 versus active warming 2 (with additional warming mechanisms in**
5   **both groups)**
6   •   Forced air warming versus warmed blanket (two direct and two indirect studies)
7   o   Forced air warming blanket (Bair Hugger®) versus warmed blanket (changed every
8   15 minutes, temperature not stated) (Stevens 2000)
9   ▪   Both groups had a head covering, which was not said to be warmed;
10   o   Forced air warming blanket (Bair Hugger®; medium, presumed 37°C) versus warmed
11   cotton blanket (changed every 20 minutes, stored 66 to 77°C)
12   ▪   Both groups had a warmed head covering which was replaced every 20 minutes
13   (Giuffre 1991);
14   •   Radiant heater versus warmed blankets (one study)
15   o   Radiant heater (2 radiant lights 71cm from skin) versus warmed cotton blanket
16   (changed every 20 minutes, stored 66 to 77°C)
17   ▪   Both groups had a warmed head covering which was replaced every 20 minutes
18   (Giuffre 1991).
19
20   **C. Active warming 1 (subtype 1) versus active warming 1 (subtype 2)**
21   •   Forced air warming blanket 1 versus forced air warming blanket 2
22   o   Full body forced air warming blanket (Bair Hugger®, max setting) versus full body
23   forced air warming blanket (Warm Touch®, max setting) (Bräuer 2004, indirect);
24   •   Radiant heater 1 versus radiant heater 2
25   o   Radiant heater (Aragona Thermal Ceilings; 1kW, 75cm from chest) versus radiant
26   heater (self assembled): 4 Hydrosun 500 halogen lamps (4x160W; 60cm from
27   patient's chest) (Bräuer 2004, indirect).
28
29   **D. Active warming versus thermal insulation**
30   •   Radiant heater (Thermal Ceiling; 500W; about 65cm above body surface) versus
31   reflective blanket (type not stated) plus 3 cotton blankets (Bredahl 1995)
32
33   **E. Thermal insulation versus usual care**
34   **E1. Thermal insulation versus usual care with active warming in both groups**
35   •   Reflective blanket (type not stated) plus reflective head covering (thermal insulation)
36   versus usual care (Hershey 1997):
37   o   Both groups had two warmed thermal blankets (not stated to be changed;
38   temperature not stated; active warming).
39
40   **F. Thermal insulation 1 versus thermal insulation 2, with active warming in both groups**

F1. Thermal insulation 1 versus thermal insulation 2, with active warming in both groups

- Reflective blanket plus reflective head covering (thermal insulation) versus reflective blanket (thermal insulation) (Hershey 1997):
  - o Both groups had two warmed thermal blankets (not stated to be changed; temperature not stated; active warming).

Outcomes

The studies measured the following outcomes:

Primary outcomes:

Two studies recorded the number of patients with IPH (Karayan 1996; Vanni 2003), but several measured the core temperature at different times. The GDG decided that the most useful outcome measures, where given, were the rate of increase in temperature and the time taken to reach normothermia.

Four studies recorded the core temperature at the tympanic membrane (Alfonsi 2003; Stevens 2000; Summers 1990; Vanni 2003); one measured pulmonary artery temperatures (Karayan 1996); two measured oesophageal temperatures (Weyland 1994; Bräuer 2004, indirect); two rectal (Bredahl 1995; Jackson 1997) and three oral (Giuffre 1991; Hershey 1997; Lennon 1990).

METHODOLOGICAL QUALITY OF INCLUDED STUDIES

An adequate method of sequence generation was recorded in four studies (Alfonsi 2003, computer generated; Giuffre 1991, shuffled envelopes; Hershey 1997, random numbers table; Summers 1990, coin toss); there was an inadequate method in one study (Stevens 2000; alternation) and the method was unclear in the remaining studies.

A partially adequate method of allocation concealment was reported in three studies (Alfonsi 2003: sequentially numbered opaque envelopes; Lennon 1990, sealed envelopes; Vanni 2003: sequentially numbered opaque envelopes); allocation concealment was inadequate in one study (Stevens 2000; alternation) and unclear in the remaining studies.

Two studies reported that the outcome assessors were blinded for shivering (Alfonsi 2003; Vanni 2003) and two that they were not (Hershey 1997; Jackson 1997), the others did not say. It was unlikely that the patients were blinded, except for studies in ICU (Weyland 1994; Bräuer 2004, indirect).

Most of the studies demonstrated baseline comparability. Two studies were not comparable for the length of time in the theatre. In Summers (1990), the warming group was longer by 35

1   minutes, and in Hershey (1997) the reflective blanket group mean was 32 and 49 minutes
2   respectively longer than the reflective blanket + hat and control groups. One study (Stevens
3   2000) was not comparable for the proportion of orthopaedic patients (more in control group:
4   3.6 versus 13.2%).
5
6   For the preoperative and intraoperative treatment studies (Karayan 1996; Vanni 2003) the
7   temperature at baseline was comparable between the groups. For the postoperative treatment
8   studies, the temperature on arrival in PACU/ICU was reported for all studies except Stevens
9   (2000); Weyland (1994); Bräuer (2004), indirect. All except Summers (1990) showed
10   comparable temperatures at baseline (Figure 1). This study had a significantly lower mean
11   baseline temperature on arrival in PACU for the intervention group (0.38°C). We note that two
12   of the comparisons in Hershey (1997) showed a difference in baseline of 0.2°C, but this was
13   not statistically significant, and there was a difference in the median of 0.3°C for Bredahl
14   (1995), which the authors said 'did not yield intergroup differences'.
15
16   **Figure 1: Baseline core temperatures**

Review: IPH
Comparison: 10 active warming vs other intevention/none (postop, treatment)
Outcome: 03 Core temperature at baseline

Study or sub-category	Warming Device N	Warming Device Mean (SD)	usual care N	usual care Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
02 baseline							
Alfonsi 2003	9	35.20(0.30)	9	35.20(0.40)		6.98	0.00 [-0.33, 0.33]
Bredahl median	15	34.90(0.00)	15	35.20(0.00)			Not estimable
Giuffre 1991a	29	34.40(0.42)	30	34.46(0.42)		16.22	-0.06 [-0.27, 0.15]
Giuffre 1991b	30	34.46(0.42)	31	34.43(0.43)		16.38	0.03 [-0.18, 0.24]
Giuffre 1991c	29	34.40(0.42)	30	34.46(0.42)		16.22	-0.06 [-0.27, 0.15]
Hershey 1997a	48	34.80(0.72)	46	35.00(0.59)		10.56	-0.20 [-0.47, 0.07]
Hershey 1997b	46	34.80(0.76)	46	35.00(0.59)		9.64	-0.20 [-0.48, 0.08]
Hershey 1997c	48	34.80(0.72)	46	34.80(0.76)		8.31	0.00 [-0.30, 0.30]
Jackson 1997	10	35.20(0.60)	10	35.20(0.40)		3.73	0.00 [-0.45, 0.45]
Lennon 1990	15	34.30(0.50)	15	34.30(0.60)		4.77	0.00 [-0.40, 0.40]
Summers 1990	45	35.00(1.18)	46	35.38(0.45)		5.49	-0.38 [-0.75, -0.01]
Vanni intra 2003	10	35.20(1.20)	10	35.10(1.10)		0.73	0.10 [-0.91, 1.11]
Vanni pre+intra 2003	10	34.90(0.90)	10	35.10(1.10)		0.96	-0.20 [-1.08, 0.68]

-1   -0.5   0   0.5   1
Favours usual care   Favours warming dev

17
18
19   Three studies described an *a-priori* power calculation (Alfonsi 2003; Bredahl 1995; Hershey
20   1997). In Alfonsi (2003), the power calculation required 9 patients per group to achieve a
21   difference of 0.4°C. The Bredahl (1995) study required 13 patients in each group to achieve a
22   core temperature change of 0.5°C. The Hershey (1997) study calculated a sample size of 48
23   per group was required to detect a medium effect size of F=0.25.
24
25   One study reported more than 20% of dropouts for one outcome (6/15 (40%) of the forced air
26   group did not have the temperature recorded at 90 minutes) (Lennon 1990). In the Stevens
27   (2000) study 3/60 (5%) of the forced air group and 4/60 (7%) of the control group had
28   incomplete data. The Hershey (1997) study had missing data for 2/48 (4%) in the reflective
29   blankets and reflective blanket + hat groups.
30
31   Overall, three studies were regarded as having potential for bias (Stevens 2000, allocation
32   concealment; Hershey 1997 and Summers 1990, baseline comparability). These were treated
33   with caution and examined in sensitivity analyses. The Lennon (1990) outcome at 90 minutes

1   was also potentially biased.

2

3   **RESULTS**

4   **I. Treatment in the preoperative phase**

5   **A. Active warming versus usual care (cross phase comparison)**

6   One study (Vanni 2002) in 20 patients investigated the additive effect of preoperative warming

7   to intraoperative warming for the treatment of IPH.

8

9   **1. Core temperature at different intraoperative times**

10 Data were extracted from a graph for a series of intraoperative times (Figure 2). The

11 confidence intervals at 30, 60 and120 minutes were too wide to determine if there was a

12 difference between interventions.

13

14 **Figure 2: Core temperature: intraoperative temperature; active warming (pre and**

15 **intraoperative) versus active warming (intraoperative)**

16

17 NB: Scale -4 to +4

18

19 **2. Core temperature: lowest intraoperative temperature**

20 The lowest intraoperative measurements were extracted from graphs (Figure 3) and were

21 found at 30 minutes for the pre and intraoperative warming group and 120 minutes for the

22 intraoperative warming group. The confidence interval is too wide to determine if there was a

23 difference between interventions.

24 .

25 **Figure 3: Core temperature: lowest intraoperative temperature; active warming (pre and**

26 **intraoperative) versus active warming (intraoperative)**

```
Review:        IPH
Comparison:    23 active warming (pre+intra) vs Active warming device (intra only) treatment
Outcome:       01 Core temperature lowest temperature intraoperatively

Study                          Warming (pre+intra)          Warming (intra only)        WMD (fixed)        Weight        WMD (fixed)
or sub-category         N      Mean (SD)           N        Mean (SD)                   95% CI             %             95% CI

02 forced air warming
  Vanni 2003             10     36.26(0.79)         10       35.82(1.29)                                    100.00        0.44 [-0.50, 1.38]
Subtotal (95% CI)        10                         10                                                      100.00        0.44 [-0.50, 1.38]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.92 (P = 0.36)

Total (95% CI)           10                         10                                                      100.00        0.44 [-0.50, 1.38]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.92 (P = 0.36)

                                         -4       -2        0        2        4
                                         Favours intra only   Favours pre & intra
```
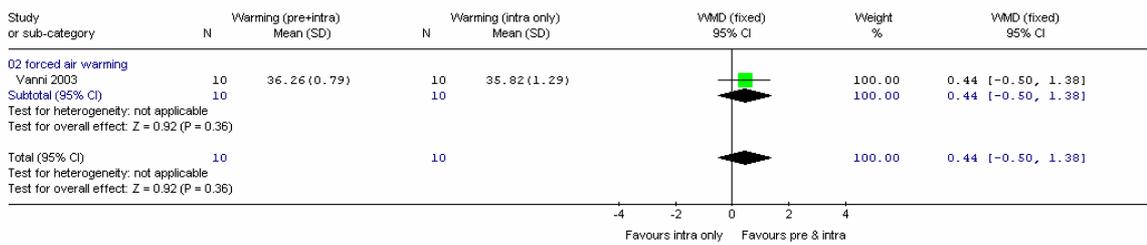
3. Core temperature: end of surgery

At the end of surgery, there was no significant difference in the core temperature at the end of surgery, although the confidence interval is fairly wide (Figure 4).

Figure 4: Core temperature: end of surgery; active warming (pre and intraoperative) versus active warming (intraoperative)

```
Review:        IPH
Comparison:    21 Active warming versus usual care - treatment - preop
Outcome:       02 Core temperature: end of surgery

Study                          Pre+Intra WD                 Intra WD                    WMD (fixed)        Weight        WMD (fixed)
or sub-category         N      Mean (SD)           N        Mean (SD)                   95% CI             %             95% CI

01 Pre+intra FAW vs intra FAW
  Vanni 2003             10     36.91(0.30)         10       36.91(0.50)                                    100.00        0.00 [-0.36, 0.36]
Subtotal (95% CI)        10                         10                                                      100.00        0.00 [-0.36, 0.36]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.00 (P = 1.00)

Total (95% CI)           10                         10                                                      100.00        0.00 [-0.36, 0.36]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.00 (P = 1.00)

                                         -1      -0.5       0       0.5       1
                                         Favours intra WD   Favours pre+intra WD
```
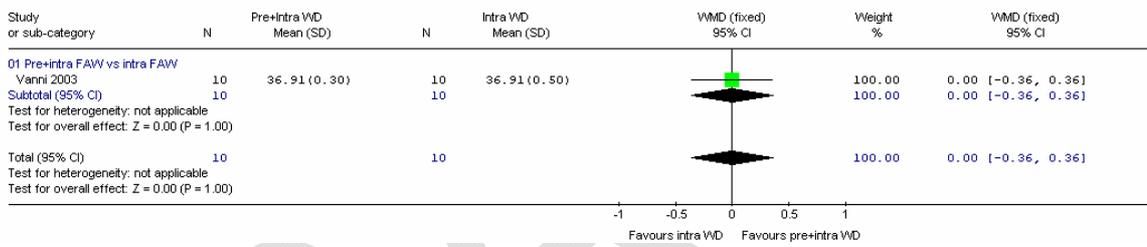
4. Time to reach 36.0°C

The time to reach 36.0°C was estimated from a graph. For the group that was warmed preoperatively, it took between 60 and 75 minutes for the core temperature to exceed 36.0°C (36.5°C was reached) from 34.9°C. Once the temperature was at 36.5°C it did not fall below 36.0°C intraoperatively during further warming.

5. Shivering

Vanni (2003) evaluated shivering as absent, mild (when only detected by ECG artefacts) or severe (when clinically obvious). Only mild shivering was observed in Vanni (2003), and the GDG decided that shivering evaluated with ECG artefacts was not an appropriate method of assessment, because other involuntary movements (e.g. in those with Parkinson's disease) may be recorded. Therefore the incidence of mild shivering was not considered for this study, and there was no incidence of severe shivering in either group.

II. Treatment in the pre and intraoperative phases

A. Active warming versus usual care

One study (Vanni 2003) in 20 patients compared full body forced air warming in both the pre and intraoperative phases versus usual care for the treatment of IPH; all patients received room temperature fluids at 8 to 10ml/kg/h.

1

2 **1. Core temperature at different intraoperative times**

3 Vanni (2003) reported a series of intraoperative temperature measurements in 20 patients and

4 data were extracted from graphs.

5

6 The analysis showed a large significant difference between interventions at all durations, with

7 the patients warmed in the pre and intraoperative phases having higher mean core

8 temperatures than those given usual care. However, at all times the confidence intervals are

9 wide.

10

11 **Figure 5: Core temperature intraoperatively – forced air warming in the pre and**

12 **intraoperative phases versus usual care**

Review: IPH (IPHtreatment)
Comparison: 06 Pre+intra active warming device vs usual care
Outcome: 17 Core temperature intra-operatively

Study or sub-category	Warming N	Mean (SD)	Usual care N	Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 30 mins							
Vanni 2003	10	36.26(0.79)	10	35.22(1.09)		100.00	1.04 [0.21, 1.87]
Subtotal (95% CI)	10		10			100.00	1.04 [0.21, 1.87]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 2.44 (P = 0.01)							
02 60 mins							
Vanni 2003	10	36.61(0.40)	10	35.27(1.19)		100.00	1.34 [0.56, 2.12]
Subtotal (95% CI)	10		10			100.00	1.34 [0.56, 2.12]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 3.38 (P = 0.0007)							
03 120 mins							
Vanni 2003	10	36.41(0.79)	10	35.12(1.19)		100.00	1.29 [0.40, 2.18]
Subtotal (95% CI)	10		10			100.00	1.29 [0.40, 2.18]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 2.86 (P = 0.004)							

-4   -2   0   2   4
Favours usual care   Favours warming

13

14 NB: Scale -4 to +4

15

16 **2. Core Temperature – lowest intraoperative temperature measured**

17 The lowest temperatures for the treatment group and control group were at 30 and 120

18 minutes in Vanni (2003). The confidence interval is wide, but there is a large statistically

19 significant difference between groups; mean difference: 1.14°C (95% CI 0.25, 2.03) for a core

20 temperature of 35.1°C for the control group.

21

22 **Figure 6: Lowest intraoperative temperature**

Review: IPH
Comparison: 24 active warming (pre+intra) vs usual care: treatment of IPH
Outcome: 01 Core temperature lowest temperature intraoperatively

Study or sub-category	Warming (pre+intra) N	Mean (SD)	Warming (intra only) N	Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
02 forced air warming							
Vanni 2003	10	36.26(0.79)	10	35.12(1.19)		100.00	1.14 [0.25, 2.03]
Subtotal (95% CI)	10		10			100.00	1.14 [0.25, 2.03]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 2.52 (P = 0.01)							
Total (95% CI)	10		10			100.00	1.14 [0.25, 2.03]
Test for heterogeneity: not applicable							
Test for overall effect: Z = 2.52 (P = 0.01)							

-4   -2   0   2   4
Favours intra only   Favours pre & intra

23

24 NB: Scale -4 to +4

25

26 **3. Core temperature – final intraoperative temperature (Figure 7)**

1   The Vanni (2003) study in 20 patients reported the core temperature at the end of the

2   intraoperative period (duration of surgery was 167 minutes (SD 57) for the control group and

3   175 min (SD 66) for the intervention group). There is a large statistically significant difference

4   between groups; but the confidence interval is wide.

5

6   **Figure 7: Final intraoperative temperature**

7
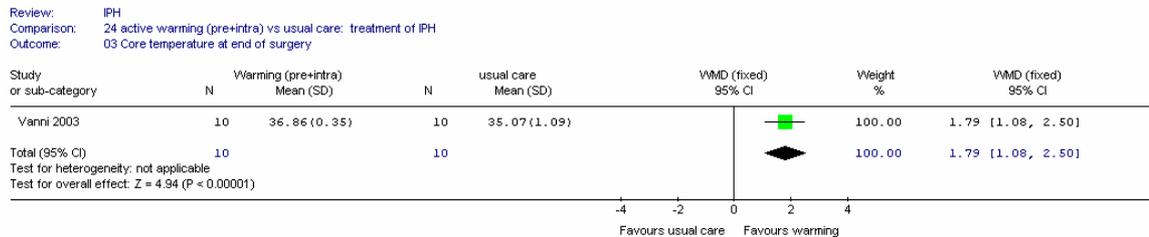
8   NB: scale -4 to +4

9

10   **4. Incidence of hypothermia at the end of anaesthesia**

11   One study (Vanni 2003) in 20 patients reported the incidence of hypothermia (core

12   temperature less than 36.0°C) at the end of anaesthesia (duration of surgery was 167 minutes

13   (SD 57) for the control group and 175 minutes (SD 66) for the intervention group. There was a

14   very large effect, with all patients being hypothermic in the control group and two in the

15   intervention group. The confidence interval is very wide.

16

17   **Figure 8: Incidence of hypothermia at end of anaesthesia**

18
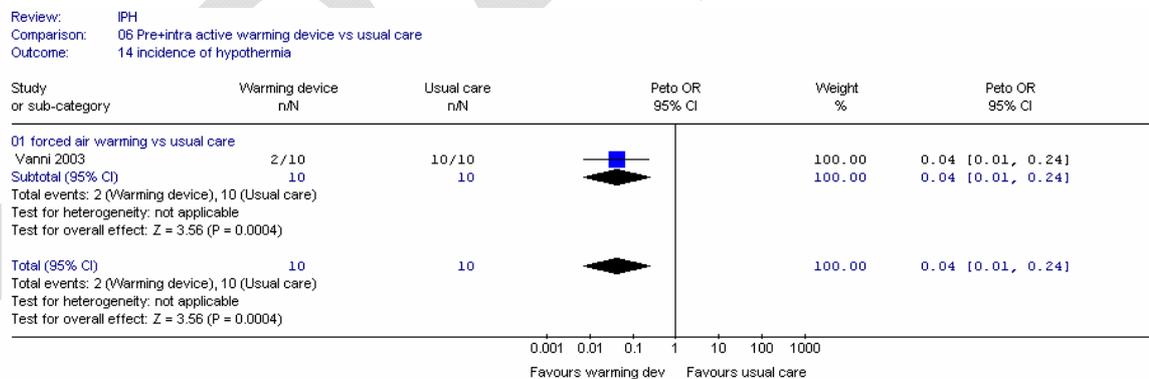
19   NB: Scale 0.001 to 1000.

20

21   **5. Incidence of shivering**

22   Vanni (2003) categorised shivering as absent, mild (when only detected by ECG artefacts) or

23   severe (when clinically obvious). Shivering was assessed by an independent observer blinded

24   to the study treatment. The GDG suggested that as any involuntary movement (e.g. in those

25   with Parkinson's disease) would be recorded by ECG artefacts, this would not be an accurate

26   method of assessing shivering. Therefore only shivering classified severe was considered for

27   this study. However, no patients experienced severe shivering in this study.

28

29   **6. Time to reach 36.0**°C

The time to regain a core temperature of 36°C was reported as 57 (SD 15) minutes in the control group and from 15 to 30 minutes in the three patients in the warming groups (pre plus intraoperative phase = 2 patients; intraoperative only = 1 patient).

III. Treatment in the intraoperative phase

Two studies (Karayan 1996; Vanni 2001) with 38 patients compared the effectiveness of forced air warming compared with usual care in patients undergoing surgery under general anaesthesia.

In the Karayan (1996) study, 18 patients undergoing abdominal aortic surgery received upper body (equivalent to 24% of the body surface area) forced air warming (set at 'high'); the forced air blanket was covered with additional 2 cotton sheets and the usual care group received a warm cotton sheet. All patients received warmed IV fluids.

In the Vanni (2001) study, 20 patients undergoing abdominal surgery lasting at least 2 hours received forced air warming (42 to 46°C); the blanket covered the thorax, shoulders, arms and hands and was covered by an additional cotton sheet. Patients in the usual care group received two cotton sheets covering the thorax, shoulders, arms and hands. All patients received fluids kept at the theatre temperature (21.5 to 22°C) before infusion.

In Vanni (2001), patients were hypothermic before induction of anaesthesia (35.2°C [SD 1.2]; 35.1°C [SD 1.1]). In Karayan (1996), both groups were above 36.0°C before induction of anaesthesia.

In the Karayan (1996) study, warming (or no warming) commenced when patient's core temperature fell below 36.0°C. The core temperature in the patients randomised to the forced air warming group fell below 36.0°C at 2 hours after induction.

The delays in activating the warming system were for the following reasons:
- Use of a warming system before induction would require a cover on the lower limbs: the authors considered this a risk in patients with aorto-iliac occlusive disease because of the risk of burning.
- Insertion of invasive monitoring in the upper part of the body would have been precluded.

1. Core temperature at different intraoperative times

For the Karayan (1996) study the following results are presented: 1 hour after induction (although no warming at this stage - shown for completeness); 2 hours after induction (when warming commenced); 3 hours after induction (1 hour of warming), 4 hours after induction (2 hours of warming), 5 hours after induction (3 hours of warming) and 6 hours after induction (4

1   hours of warming). Results for Vanni (2001) are presented at 30 minutes and combined with

2   Karayan (1996) at 1 hour of warming and 2 hours of warming.

3

4   The mean difference was not significant at 30 minutes (Vanni 2003). In the meta-analysis of

5   the two studies with 38 patients at 60 and 120 minutes, there was a significantly higher mean

6   temperature for the warmed group; 60 minutes: WMD 0.81°C (95% CI 0.36, 1.26; and 120

7   minutes: WMD 1.22°C (95% CI 0.74, 1.69). In each case the confidence interval is fairly wide.

8

9   At 3 hours and 4 hours, data are available from one study (Karayan 1996) with 18 patients:

10   there was a significantly higher mean temperature for the warmed group, although the

11   confidence interval is wide.

12

13   **Figure 9: Core temperature at different intraoperative times**

14

15
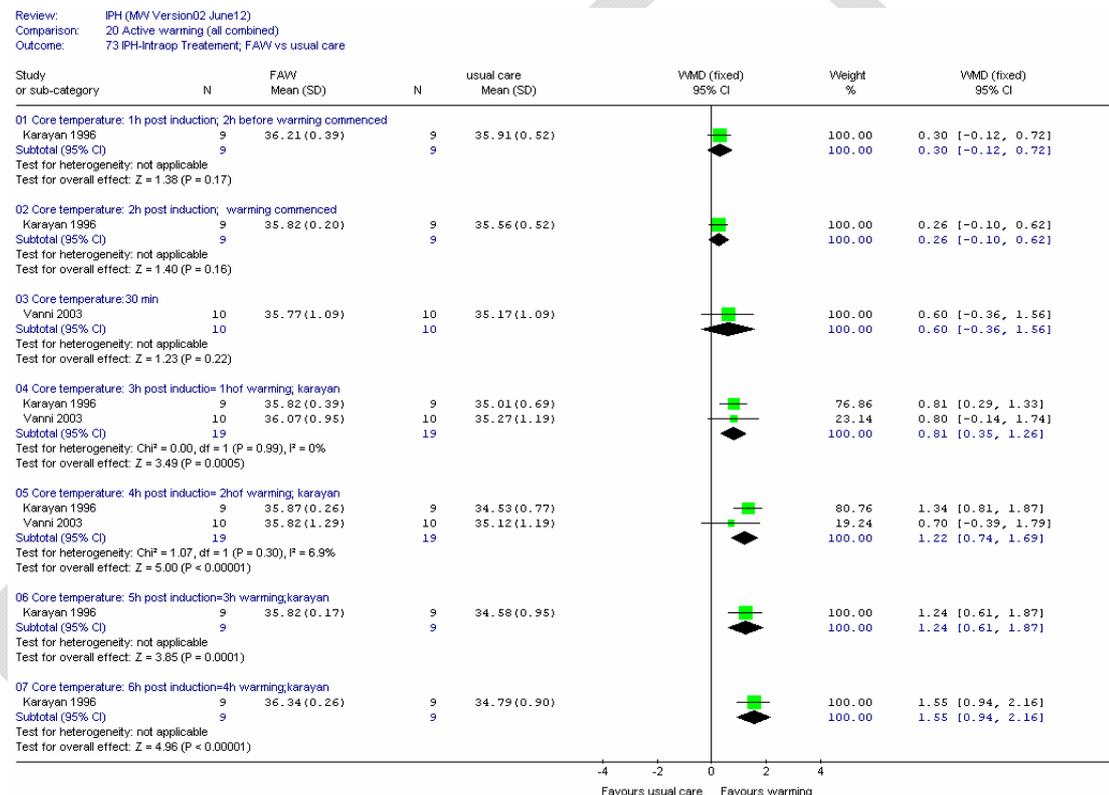
16   **2. Incidence of hypothermia**

17   The Vanni (2003) study reported the incidence of hypothermia on arrival in the recovery room.

18   This showed that all 10 patients in the usual care group had hypothermia, compared with only

19   1 of 10 in the warmed group.

20

21   Karayan (1996) also reported that all unwarmed patients were hypothermic at end of surgery.

22   Mean core temperature for the warmed group at the end of surgery was 36.5ºC (SD 0.3ºC).

23   Then assuming that none of these patients were hypothermic, the comparison in this study

24   becomes: 0/9 versus 9/9 patients hypothermic, and the two studies can be combined. Meta-

1   analysis showed a highly significantly lower incidence of hypothermia for the warmed group;
2   Peto OR 0.03 (95%CI 0.01, 0.09). The confidence interval is very wide.
3
4   **Figure 10: Incidence of hypothermia**

Review: IPH (MW Version02 June12)
Comparison: 20 Active warming (all combined)
Outcome: 40 Incidence of hypothermia

Study or sub-category	Warming n/N	Usual care n/N	Peto OR 95% CI	Weight %	Peto OR 95% CI
Karayan 1996	0/9	9/9		47.77	0.02 [0.00, 0.14]
Vanni 2003	1/10	10/10		52.23	0.03 [0.01, 0.18]
Total (95% CI)	19	19		100.00	0.03 [0.01, 0.09]

Total events: 1 (Warming), 19 (Usual care)
Test for heterogeneity: Chi² = 0.07, df = 1 (P = 0.80), I² = 0%
Test for overall effect: Z = 5.70 (P < 0.00001)

0.001 0.01 0.1 1 10 100 1000
Favours usual care   Favours warming

5
6
7   **3. Time to reach 36.0°C**
8   The time to regain a core temperature of 36.0ºC was reported in Vanni (2003) as 57 (SD 15)
9   minutes in the control group and from 15 to 30 minutes in the three patients in the warming
10   groups (pre and intraoperative phase = 2 patients; intraoperative only = 1 patient).
11
12   In Karayan (1996), the time to regain a core temperature of 36.0°C was around 3 hours in the
13   warmed group while the control group had not regained a core temperature of 36.0ºC at the
14   last measurement at 4 hours.
15
16   **IV. Treatment in the postoperative phase**
17   **A. Active warming versus usual care**
18   **1. Core temperature in the postoperative period**
19   Two studies with 18 and 20 patients recorded the core temperature (Jackson 1997, rectal;
20   Alfonsi 2003, tympanic temperature); temperatures in the Jackson (1997) study were recorded
21   at various times postoperatively. Generally, the confidence interval is fairly wide, but at longer
22   times (60 minutes and above) the mean temperature is significantly higher for the active
23   warming group. At 60 minutes, the mean control group temperature was still below 36.0°C,
24   but that for the warmed group was above. It is noted that rectal temperatures were measured
25   for the Jackson (1997) study. There was no significant difference in tympanic temperature at
26   37 minutes in the Alfonsi (2003) study.
27
28   **Figure 11: Core temperature**

Review: IPH (Version pre 140907)
Comparison: 08 active warming vs usual care (postop, treatment)
Outcome: 02 Core temperature
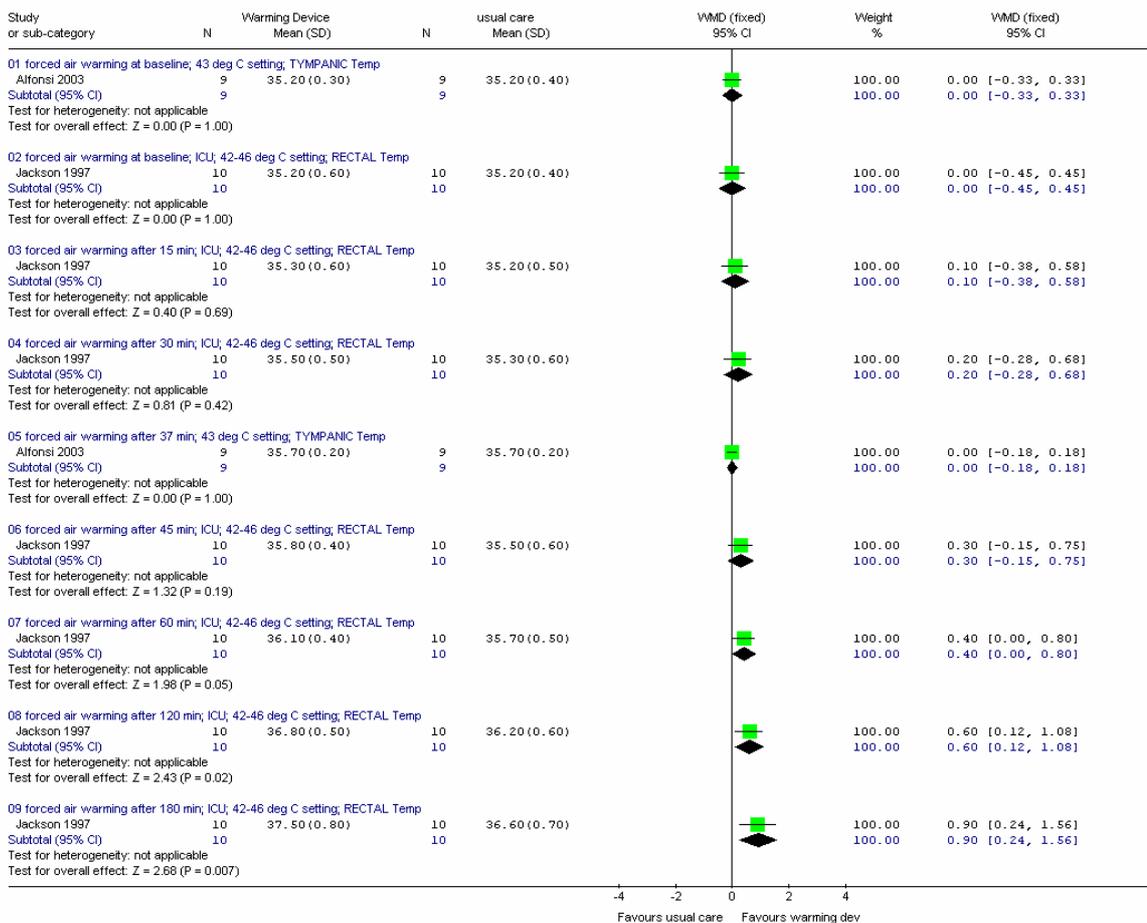
NB: Scale -4 to +4

2. Time taken to increase the temperature

One study (Weyland 1994) in ICU patients reported individual patient data for the time taken to increase the temperature from 35.0ºC to 35.5ºC; from 35.5ºC to 36.0ºC and from 36.0°C to 36.5°C. These data were extracted from a graph. In this study, 12 patients were allocated to radiant heater, of whom 10 had temperatures that fell to 35.0ºC; these patients took a mean of 25.1 minutes (SD 8.6) to regain a temperature of 35.5ºC; a further 23.3 minutes (SD 5.1) to regain 36ºC; and a further 25.2 minutes (SD 6. 8) to raise the temperature to 36.5°C. 12 patients were allocated to an electric blanket, of whom 11 had temperatures that fell to 35ºC; these patients took a mean of 54.4 minutes (SD 34.0) to regain a temperature of 35.5ºC and a further 44.8 minutes (SD 13.0) to regain 36ºC; and a further 41.9 minutes (SD 22.5) to raise the temperature to 36.5°C. These results compared with the 11 patients in the control group, of whom 10 had temperatures that fell to 35.0ºC; these patients took a mean of 59.7 minutes (SD 40.3) to regain a temperature of 35.5ºC; a further 51.2 minutes (SD 20.2) to regain 36ºC and 11 took a further 48.5 minutes (SD 25.6) to raise the temperature to 36.5°C.

Figure 12: Time to raise the temperature
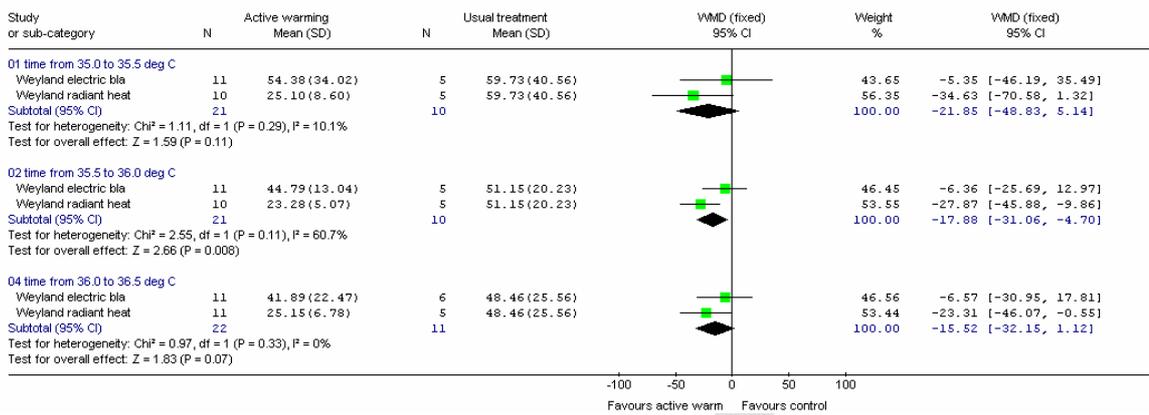
The meta-analysis of the two comparisons showed some heterogeneity in the time to raise the temperature from 35.5 to 36.0°C (I^2=61%; p=0.11), and a subgroup analysis by type of active warming was carried out.

Figure 13a: Time to raise temperature (subgroup analysis for radiant heaters)
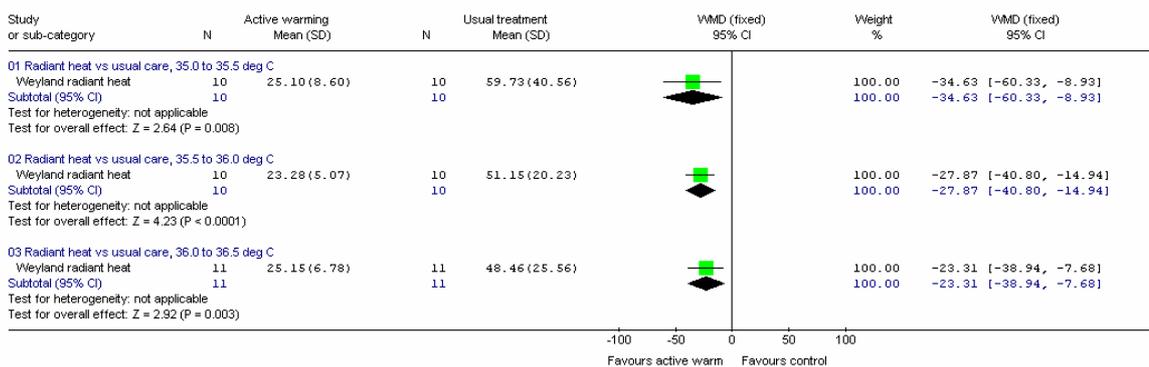
For the radiant heater (1000W) versus usual care, in 23 patients, there was a statistically significant difference between interventions and the difference in time taken to raise the temperature by 0.5°C was similar for the different initial temperatures.

Figure 13b: Time to raise temperature (subgroup analysis for electric blankets)
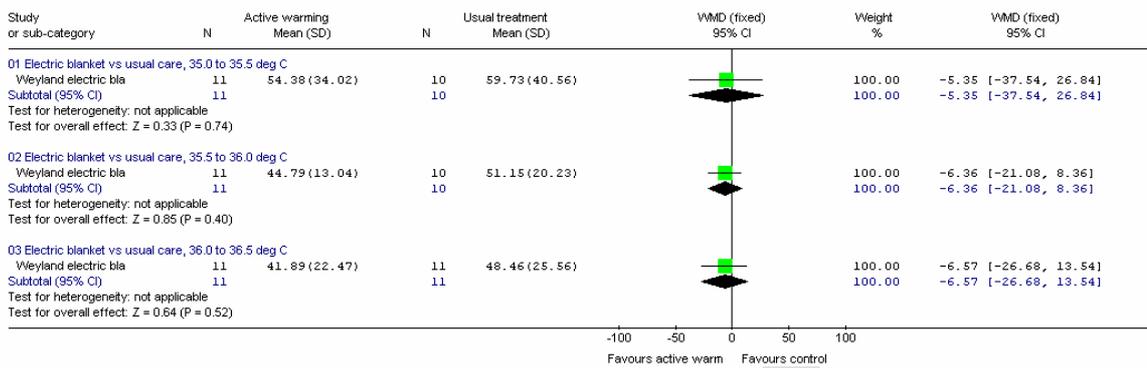
For the electric blanket (50W) intervention versus usual care, in 23 patients, there was no significant difference between electric blanket and usual care in the time taken to raise the temperature from 35.0°C to 35.5°C; 35.5°C to 36.0°C or 36.0°C to 36.5°C.

3. Rate of temperature change (°C/h)

The indirect study Bräuer (2004) in post-bypass patients recorded the median rate of increase of temperature, giving p values for the difference. These were converted to standard errors and used in the generic inverse variance option of the Review Manager software. There were 20 patients in each comparison.

Bräuer (2004) compared two forced air warming blankets, and two radiant heaters with a polyester filled blanket, and found statistically significant differences, compared with usual care, for both forced air warming blankets, but only for one radiant heater – a self assembled set of four 160W lamps. These differences in the median temperature were clinically significant.

Figure 14: Rate of warming
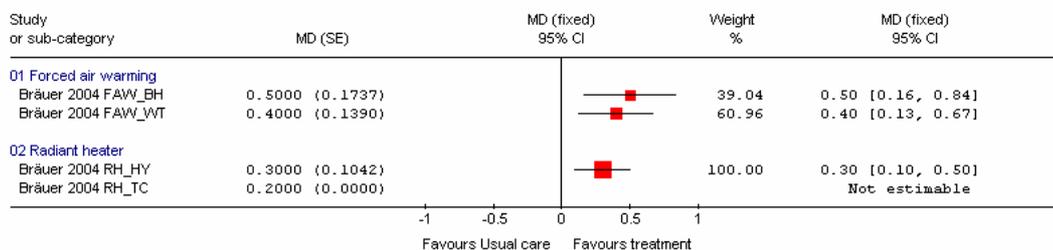
4. Incidence of shivering

Two studies with 55 patients (Jackson 1997; Weyland 1994) assessed shivering in the recovery room, Jackson for different time periods postoperatively and Weyland over the whole monitoring period (Figure 15). Generally, the confidence interval is too wide to draw conclusions.

1

2 **Figure 15: Incidence of shivering**

3

4
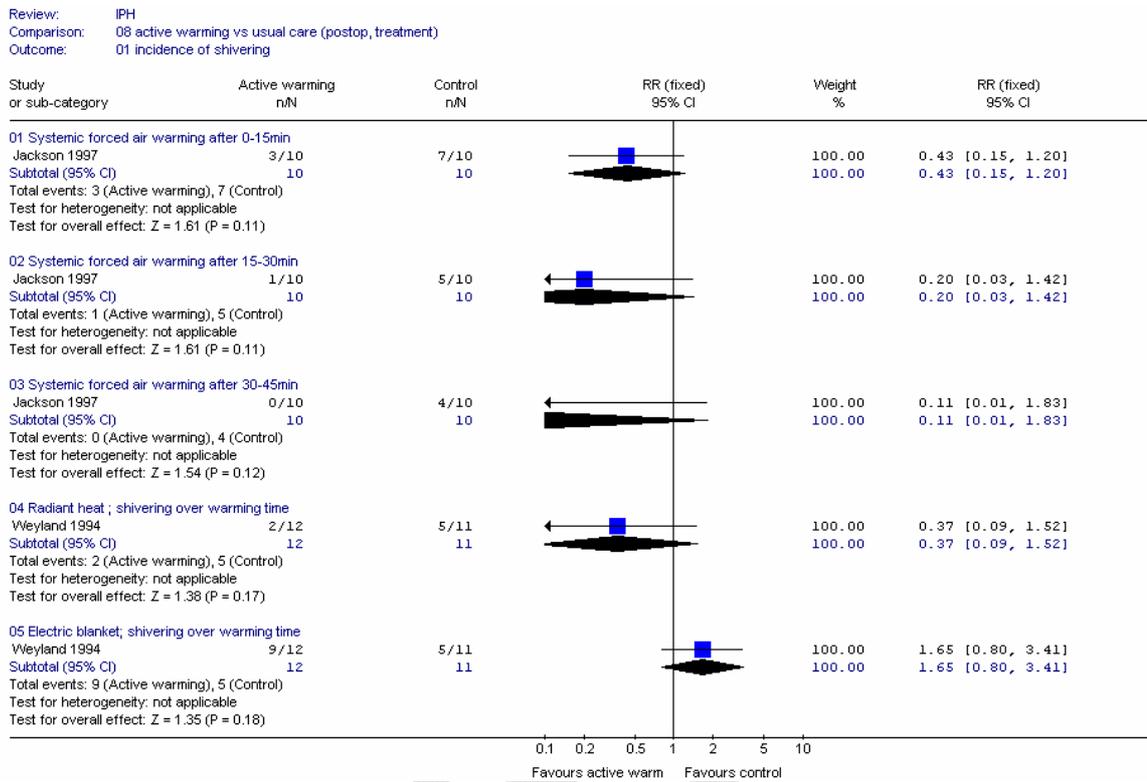
5 **Postoperative complications**

6 **5. Patient's perception of cold**

7 One study with 18 patients (Alfonsi 2003) reported the patient's perception of cold at the end

8 of the forced air warming period (Figure 16).

9

10 **Figure 16: Patient's perception of cold**
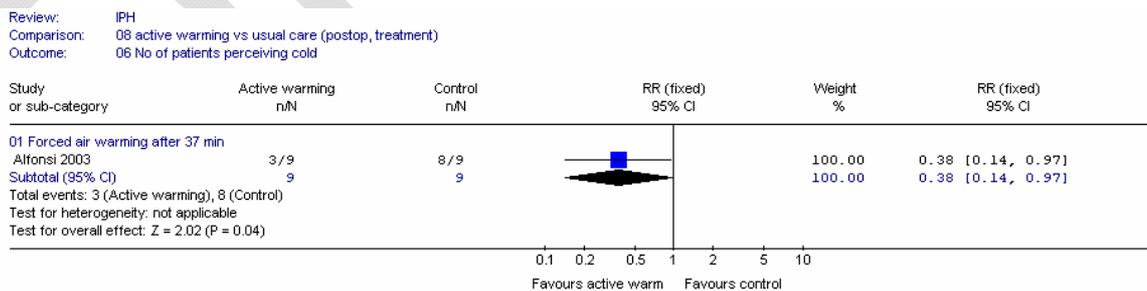
11

12

13 There was a statistically significant difference in the number of patients perceiving that they

14 were cold, although the confidence interval is wide. The relative risk was 0.38, i.e. about 3

15 times the risk for the control patients. This corresponds to a number needed to treat of 2 (95%

16 CI 2, 6), for a control group risk of 89%.

17

18 **6. Patient's perception of pain**

19 One study with 18 patients (Alfonsi 2003) reported the patient's perception of pain at the end

1   of the forced air warming period (Figure 17). There was no significant difference in the number

2   of patients perceiving pain, although the confidence interval is fairly wide.

3

4   **Figure 17: Patients' perception of pain**

Review:	IPH
Comparison:	08 active warming vs usual care (postop, treatment)
Outcome:	07 No of patients perceiving pain

Study or sub-category	Active warming n/N	Control n/N	RR (fixed) 95% CI	Weight %	RR (fixed) 95% CI
01 Forced air warming after 37 min					
Alfonsi 2003	4/9	5/9		100.00	0.80 [0.31, 2.04]
Subtotal (95% CI)	9	9		100.00	0.80 [0.31, 2.04]
Total events: 4 (Active warming), 5 (Control)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 0.47 (P = 0.64)					

0.1 0.2 0.5 1 2 5 10
Favours active warm   Favours control

5

6
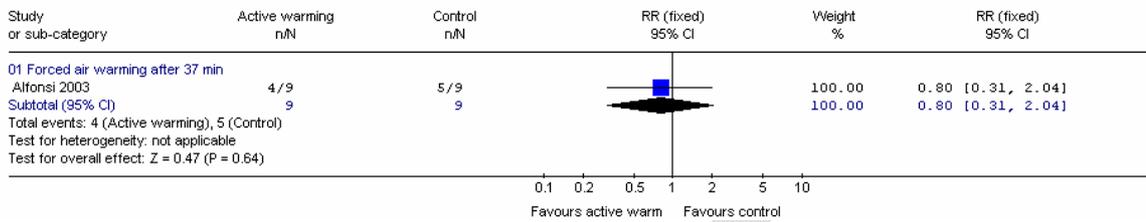
7   We considered it useful to have an estimate of how long it took patients to warm to 36.0°C in

8   PACU (or ICU) under usual care. Therefore, the mean durations were estimated from the

9   above studies. We note these are observational data based on very small numbers of

10 patients.

1   **Table 1: Time to raise temperature for the usual care group for different studies**

Study	Location measured	Method	Initial temperature	Final temperature	Time
Jackson (n=10)	ICU	Core temperature	35.2°C (baseline)	36.2°C	120 min
Jackson (n=10)	ICU	Core temperature	35.2°C (baseline)	36.6°C	180 min
35.0°C to 35.5°C					
Weyland (n=10)	ICU	time	35.0°C	35.5°C	59.7 min (SD 40.3)
Alfonsi (n=9)	PACU	Core temperature	35.2°C (baseline)	35.7°C	37 min
Jackson (n=10)	ICU	Core temperature	35.2°C (baseline)	35.5°C	45 min
35.5°C to 36.0°C					
Weyland (n=10)	ICU	time	35.5°C	36.0°C	51.2 min (SD 20.2)
Jackson (n=10)	ICU	Core temperature	35.5°C	36.2°C	75 min
36.0°C to 36.5°C					
Weyland (n=11)	ICU	time	36.0°C	36.5°C	48.5 min (SD 25.6)
Jackson (n=10)	ICU	Core temperature	36.2°C	36.6°C	60 min

2
3

4   **B. Active warming 1 versus active warming 2**
5   **B1. Forced air warming versus warmed blanket**

1 One often-used treatment for postoperative hypothermia is warmed blankets: these may be
2 regularly changed, changed as needed, or not changed, but all are methods of active warming
3 of the patients. Four studies compared forced air warming with warmed blankets (Giuffre
4 1991; Lennon 1990; Stevens 2000; Summers 1990).
5
6 **1. Core temperature postoperatively**
7 Two studies assessed the core temperature at different times postoperatively (Summers 1990;
8 Lennon 1990). Lennon (1990) recorded oral temperatures; Summers (1990) had a baseline
9 discrepancy of 0.38°C (higher for the warmed blanket). Both studies used a forced air
10 warming device: the setting was 43°C for Lennon (1990), but was not reported for Summers
11 (1990). Lennon (1990) warmed blankets to 37°C, but did not state if the blankets were
12 changed; Summers (1990) did not state the temperature, but changed the blankets as
13 needed. The results at different times are shown in Figure 18.
14
15 The two studies show significant heterogeneity at all times except 15 minutes. The Lennon
16 (1990) study in 30 patients measured oral temperatures, which may not be closely related to
17 core temperature; Summers (1990) had a baseline difference that was comparable or bigger
18 than the difference in effect. This study also had significant difference in the time spent in
19 theatre (the forced air warming group was longer by 35 minutes). It was decided to treat
20 Summers (1990) as confounded, and draw tentative conclusions only from the Lennon (1990)
21 study, even though this was not the best method of measuring temperature. This study
22 showed that the forced air warming device was significantly more effective at rewarming than
23 a warmed blanket that probably was not changed. We note that the oral temperature of the
24 warmed blanket patients was low (below 35.0°C), indicating moderate hypothermia, and that
25 the control group did not reach 36.0°C even after 75 minutes.
26
27 **Figure 18: Temperature for different times**

```
Review:       IPH
Comparison:   09 active warming vs warmed blankets (postop treatment)
Outcome:      07 Forced air warming vs warmed blanket - core temperature
```

Study or sub-category	Forced air warming N	Mean (SD)	Warmed blanket N	Mean (SD)	WMD (fixed) 95% CI	Weight %	WMD (fixed) 95% CI
01 baseline							
Lennon 1990	15	34.30(0.50)	15	34.30(0.60)		100.00	0.00 [-0.40, 0.40]
Subtotal (95% CI)	15		15			100.00	0.00 [-0.40, 0.40]
02 after 15 min warming							
Lennon 1990	15	34.80(0.70)	15	34.30(0.60)		100.00	0.50 [0.03, 0.97]
Subtotal (95% CI)	15		15			100.00	0.50 [0.03, 0.97]
03 after 30 min warming							
Lennon 1990	15	35.00(0.70)	15	34.20(0.90)		100.00	0.80 [0.22, 1.38]
Subtotal (95% CI)	15		15			100.00	0.80 [0.22, 1.38]
04 after 45 min warming							
Lennon 1990	15	35.20(1.00)	15	34.50(1.00)		100.00	0.70 [-0.02, 1.42]
Subtotal (95% CI)	15		15			100.00	0.70 [-0.02, 1.42]
05 after 60 min warming							
Lennon 1990	15	35.80(0.60)	15	34.70(1.00)		100.00	1.10 [0.51, 1.69]
Subtotal (95% CI)	15		15			100.00	1.10 [0.51, 1.69]
06 after 75 min warming							
Lennon 1990	13	36.00(0.60)	15	35.00(1.10)		100.00	1.00 [0.35, 1.65]
Subtotal (95% CI)	13		15			100.00	1.00 [0.35, 1.65]

Test for heterogeneity: not applicable (01 baseline) — Test for overall effect: Z = 0.00 (P = 1.00)

Test for heterogeneity: not applicable (02) — Test for overall effect: Z = 2.10 (P = 0.04)

Test for heterogeneity: not applicable (03) — Test for overall effect: Z = 2.72 (P = 0.007)

Test for heterogeneity: not applicable (04) — Test for overall effect: Z = 1.92 (P = 0.06)

Test for heterogeneity: not applicable (05) — Test for overall effect: Z = 3.65 (P = 0.0003)

Test for heterogeneity: not applicable (06) — Test for overall effect: Z = 3.04 (P = 0.002)

Scale: -4 -2 0 2 4 — Favours warm blanket Favours forced air

NB: Scale -4 to +4°C

2. Time taken to increase the temperature

Two studies (Giuffre 1991; Stevens 2000) reported the time taken to increase the temperature to 36.0°C. The initial mean temperatures for the Guiffre (1991) study were 34.40°C (SD 0.42) and 34.43°C (SD 0.43) for the intervention and control groups respectively. Initial temperatures were not reported for Stevens (2000). The Guiffre (1991) study also employed a warmed head covering in all patients and recorded oral temperatures; the Stevens (2000) study recorded tympanic temperatures. For the forced air warming intervention, the setting was said to be medium, presumed to be 37°C for the Guiffre (1991) study, and 'high' for Stevens (2000). Both studies replaced the control group warmed blanket regularly (every 15 to 20 minutes); blankets in the Guiffre (1991) study were stored at 66 to 77°C and the temperature was not stated for Stevens (2000).

The results are shown in Figure 19. There was a significantly shorter time to 36.0°C for the forced air warming device in the Guiffre (1991) study, but this difference was not found in the Stevens (2000) study. Meta-analysis showed significant heterogeneity (I^2=77%, p=0.04), but there is insufficient evidence to decide the cause of the heterogeneity. However, we note that the Stevens (2000) study had potential for bias because alternation was used to assign the treatments, although the Guiffre (1991) study only recorded oral temperatures and the confidence interval was wide.

Figure 19: Time to 36.0°C
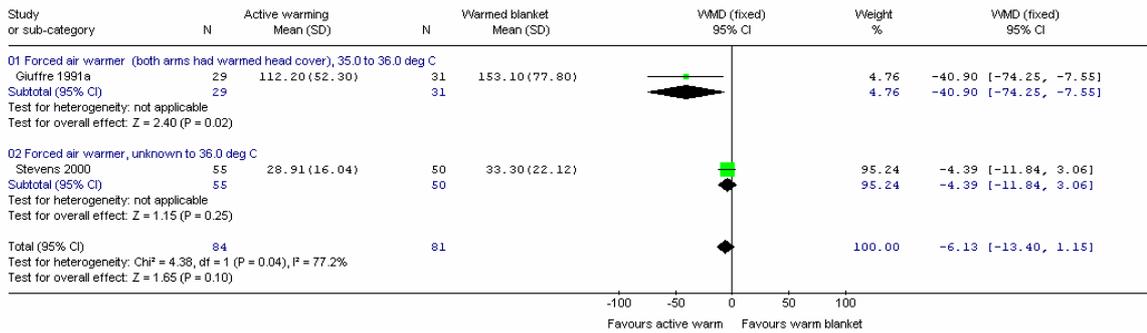
3. Rate of temperature change (°C/h)

One study (Lennon 1990) in 30 patients recorded the rate of change in temperature, giving p values for the difference. These were converted to standard errors and used in the generic inverse variance option of Review Manager. Lennon 1990 found a statistically significant difference of 0.70°C/h (95%CI 0.25, 1.14) for forced air warming compared with blankets warmed to 37°C (figure 20).

Figure 20: Rate of increase in temperature
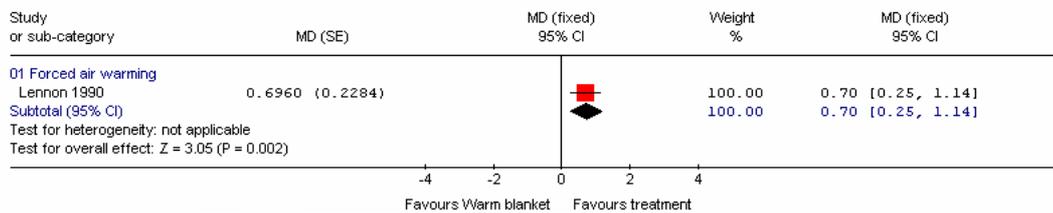
4. Time to discharge from PACU

One study with two comparisons (Guiffre 1991) recorded the time to discharge from PACU. This was the time when the nurse judged the patient ready to leave rather than when the patient actually left. This study also employed a warmed head covering in all patients and recorded oral temperatures. There was no significant difference between interventions, although the confidence interval is fairly wide (Figure 21).

Figure 21: Time to discharge from PACU (minutes)

1
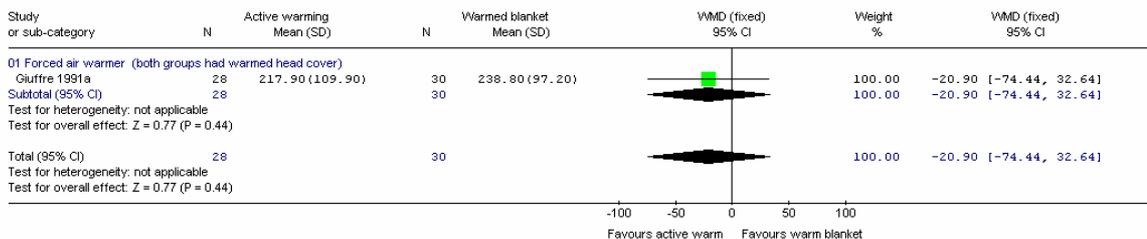
2   **5. Incidence of shivering**

3   Two studies with 121 patients (Lennon 1990; Summers 1990) assessed shivering in the

4   recovery room, Lennon (1990) at different time periods and Summers (1990) over the whole

5   monitoring period (Figure 22). Generally, the confidence interval was too wide to draw

6   conclusions, although the Lennon (1990) study showed a significantly less shivering for the

7   forced air warming group at 45 minutes and borderline significance at 15 minutes.

8

9   **Figure 22: Incidence of shivering**

Review: IPH
Comparison: 09 active warming vs warmed blankets (postop treatment)
Outcome: 11 incidence of shivering

Study or sub-category	Active warming n/N	Warmed blanket n/N	RR (fixed) 95% CI	Weight %	RR (fixed) 95% CI
01 forced air warming after 15min					
Lennon 1990	4/15	10/15		100.00	0.40 [0.16, 1.00]
Subtotal (95% CI)	15	15		100.00	0.40 [0.16, 1.00]
Total events: 4 (Active warming), 10 (Warmed blanket)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 1.97 (P = 0.05)					
02 forced air warming after 30min					
Lennon 1990	4/15	9/15		100.00	0.44 [0.17, 1.13]
Subtotal (95% CI)	15	15		100.00	0.44 [0.17, 1.13]
Total events: 4 (Active warming), 9 (Warmed blanket)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 1.70 (P = 0.09)					
03 forced air warming after 45min					
Lennon 1990	1/15	8/15		100.00	0.13 [0.02, 0.88]
Subtotal (95% CI)	15	15		100.00	0.13 [0.02, 0.88]
Total events: 1 (Active warming), 8 (Warmed blanket)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 2.09 (P = 0.04)					
04 forced air warming after 60 min					
Lennon 1990	1/15	4/15		100.00	0.25 [0.03, 1.98]
Subtotal (95% CI)	15	15		100.00	0.25 [0.03, 1.98]
Total events: 1 (Active warming), 4 (Warmed blanket)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 1.31 (P = 0.19)					
05 forced air warming after 75 min					
Lennon 1990	0/15	0/15			Not estimable
Subtotal (95% CI)	15	15			Not estimable
Total events: 0 (Active warming), 0 (Warmed blanket)					
Test for heterogeneity: not applicable					
Test for overall effect: not applicable					
06 forced air warming; shivering over warming time					
Summers 1990	14/45	15/46		100.00	0.95 [0.52, 1.74]
Subtotal (95% CI)	45	46		100.00	0.95 [0.52, 1.74]
Total events: 14 (Active warming), 15 (Warmed blanket)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 0.15 (P = 0.88)					

0.1 0.2 0.5 1 2 5 10

Favours active warm   Favours warm blanket

10

11

12   The Summers (1990) study also reported the duration of shivering (Figure 23). There was no

13   significant difference between groups, although the confidence interval is fairly wide. We also

14   note that the Summers (1990) study had significant differences in baseline characteristics

15   (time spent in the operating room).

16

17   **Figure 23: Duration of shivering**

```
Review:        IPH
Comparison:    09 active warming vs warmed blankets (postop treatment)
Outcome:       12 Shivering time (minutes)
Study                    Active warming              Warmed blanket          WMD (fixed)         Weight      WMD (fixed)
or sub-category      N   Mean (SD)          N        Mean (SD)               95% CI              %           95% CI

01 Forced air warmer
  Summers 1990       45  16.15(10.03)       46       14.13(6.64)                                 100.00      2.02 [-1.48, 5.52]
Subtotal (95% CI)    45                     46                                                   100.00      2.02 [-1.48, 5.52]
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.13 (P = 0.26)

Total (95% CI)       45                     46                                                   100.00      2.02 [-1.48, 5.52]
Test for heterogeneity: not applicable
Test for overall effect: Z = 1.13 (P = 0.26)
                                                          -10    -5    0    5    10
                                             Favours active warm   Favours warm blanket
```

1
2
3 **Postoperative Complications**

4 **6. Patient's thermal comfort**

5 One study with 91 patients (Summers 1990) reported the patient's thermal comfort 30 minutes

6 after forced air warming commenced and at the time of discharge (probably 60 minutes)

7 (Figure 24). The scale used was the Christoph comfort scale, but it was not clear what this

8 was. However, the study authors commented that the patients' perception of comfort was

9 greater for the forced air warming group, which indicates that a higher value on the scale is an

10 improvement. A statistically significant difference was found in favour of the forced air warming

11 group, but its magnitude is unclear. We also note that the Summers (1990) study had

12 significant differences in baseline characteristics (time spent in theatre).

13

14 **Figure 24: Thermal comfort**


```
Review:        IPH
Comparison:    09 active warming vs warmed blankets (postop treatment)
Outcome:       13 Thermal comfort (high is good)
Study                    Active warming              Warmed blanket          WMD (fixed)         Weight      WMD (fixed)
or sub-category      N   Mean (SD)          N        Mean (SD)               95% CI              %           95% CI

01 30 minutes
  Summers 1990       45  17.05(2.94)        46       9.20(2.70)                                  100.00      7.85 [6.69, 9.01]
Subtotal (95% CI)    45                     46                                                   100.00      7.85 [6.69, 9.01]
Test for heterogeneity: not applicable
Test for overall effect: Z = 13.26 (P < 0.00001)

02 time of discharge
  Summers 1990       45  17.66(2.34)        46       10.26(1.71)                                 100.00      7.40 [6.56, 8.24]
Subtotal (95% CI)    45                     46                                                   100.00      7.40 [6.56, 8.24]
Test for heterogeneity: not applicable
Test for overall effect: Z = 17.19 (P < 0.00001)
                                                          -10    -5    0    5    10
                                             Favours warm blanket   Favours active warm
```

15
16
17 We also recorded the time to raise the temperature to 36.0ºC for the warmed blankets group.

18 We note these are observational data.

19

20 **Table 2: Time to raise the temperature for warmed blankets groups for different studies**

Study	Location measured	Method	Initial temperature	Final temperature	Time
Lennon (n=15)	**PACU**	**Core temperature**	**34.3°C (baseline)**	**35.0°C (i.e. still hypothermic)**	**75 min**
Guiffre	**PACU**	**Time**	**35.0°C**	**36.0°C**	**153.1 min**

(n=31)					**(SD 77.8)**
Stevens	**PACU**	**Time**	**Not stated**	**36.0°C**	**33.3 min**
(n=50)					**(SD 22.1)**

1
2
3   **B2. Radiant heating versus warmed blankets**
4   One study compared radiant heating with warmed blankets (Giuffre 1991).
5
6   **1. Time taken to increase the temperature**
7   One study (Giuffre 1991) reported the time taken to increase the temperature to 36.0°C. The
8   initial mean temperatures for the Guiffre (1991) study were 34.46 (SD 0.42) and 34.43°C (SD
9   0.43) for intervention and control groups respectively. The Guiffre (1991) study also employed
10   a warmed head covering in all patients and recorded oral temperatures. The control group had
11   warmed blankets replaced regularly (every 15 to 20 minutes); blankets were stored at 66°C to
12   77°C. There was no significant difference between groups, but the confidence interval is fairly
13   wide.
14
15   **Figure 25: Time to 36.0°C**


```
Review:       IPH
Comparison:   09 active warming vs warmed blankets (postop treatment)
Outcome:      14 Time to raise temperature

Study                   Active warming          Warmed blanket       WMD (fixed)    Weight      WMD (fixed)
or sub-category      N   Mean (SD)          N    Mean (SD)           95% CI         %           95% CI

03 Radiant heater + single warmed blanket (both arms had warmed head cover), 35.0 to 36.0 deg C
  Giuffre 1991b      30  148.70(81.60)     31   153.10(77.80)                       100.00     -4.40 [-44.43, 35.63]
Subtotal (95% CI)    30                    31                                       100.00     -4.40 [-44.43, 35.63]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.22 (P = 0.83)

Total (95% CI)       30                    31                                       100.00     -4.40 [-44.43, 35.63]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.22 (P = 0.83)

                                               -100   -50    0    50   100
                                            Favours active warm    Favours warm blanket
```

16
17
18   **2. Time to discharge from PACU**
19   One study (Guiffre 1991) recorded the time to discharge from PACU. This was the time when
20   the nurse judged the patient ready to leave rather than when the patient actually left. This
21   study also employed a warmed head covering in all patients and recorded oral temperatures.
22   There was no significant difference between interventions, although the confidence interval is
23   fairly wide (Figure 26).
24
25   **Figure 26: Time to discharge from PACU (minutes)**

```
Review:      IPH
Comparison:  09 active warming vs warmed blankets (postop treatment)
Outcome:     15 Time to discharge from PACU (minutes)

Study                         Active warming           Warmed blanket        WMD (fixed)      Weight      WMD (fixed)
or sub-category          N     Mean (SD)        N       Mean (SD)             95% CI            %           95% CI

03 Radiant heater + single warmed blanket (both arms had warmed head cover)
  Giuffre 1991b          30   240.50(133.40)   30   238.80(97.20)                            100.00    1.70 [-57.36, 60.76]
Subtotal (95% CI)        30                     30                                            100.00    1.70 [-57.36, 60.76]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.06 (P = 0.96)

Total (95% CI)           30                     30                                            100.00    1.70 [-57.36, 60.76]
Test for heterogeneity: not applicable
Test for overall effect: Z = 0.06 (P = 0.96)

                                                           -100   -50    0    50   100
                                                      Favours active warm   Favours warm blanket
```

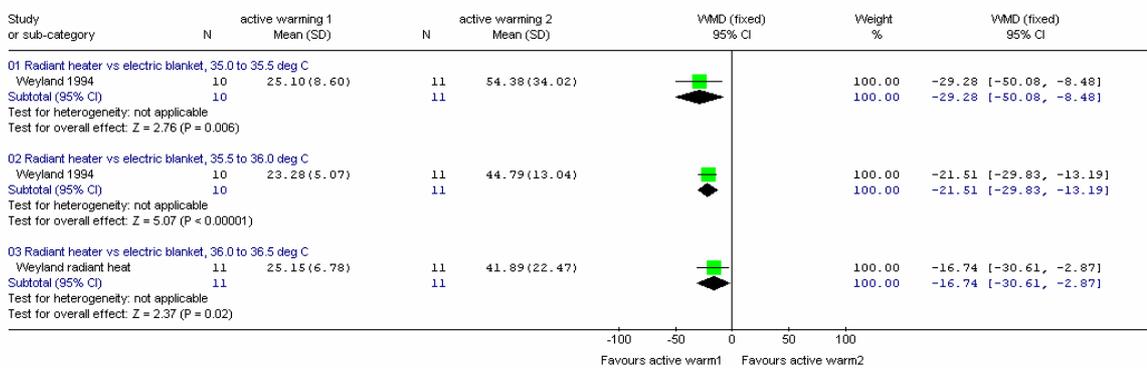**B3. Radiant heat versus electric blanket**

One study in 24 patients (Weyland 1994) compared a radiant heater (1000W) with an electric blanket (50W). Individual patient data were extracted from a graph. The oesophageal temperature was recorded.

1. Time to raise temperature

Weyland (1994) recorded the time to increase the temperature from 35.0°C to 35.5°C; 35.5°C.to 36.0°C and 36.0°C to 36.5°C. In this direct comparison, warming was significantly faster (17 to 29 minutes) for the radiant heater compared with the electric blanket, for all ranges of temperature.

Figure 27: Time to raise temperature


```
Review:      IPH
Comparison:  11 active warming 1 vs active warming 2 (postop treatment)
Outcome:     07 Time to raise temperature

Study                      active warming 1         active warming 2        WMD (fixed)      Weight      WMD (fixed)
or sub-category          N     Mean (SD)        N       Mean (SD)             95% CI            %           95% CI

01 Radiant heater vs electric blanket, 35.0 to 35.5 deg C
  Weyland 1994           10   25.10(8.60)      11   54.38(34.02)                             100.00   -29.28 [-50.08, -8.48]
Subtotal (95% CI)        10                     11                                           100.00   -29.28 [-50.08, -8.48]
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.76 (P = 0.006)

02 Radiant heater vs electric blanket, 35.5 to 36.0 deg C
  Weyland 1994           10   23.28(5.07)      11   44.79(13.04)                             100.00   -21.51 [-29.83, -13.19]
Subtotal (95% CI)        10                     11                                           100.00   -21.51 [-29.83, -13.19]
Test for heterogeneity: not applicable
Test for overall effect: Z = 5.07 (P < 0.00001)

03 Radiant heater vs electric blanket, 36.0 to 36.5 deg C
  Weyland radiant heat   11   25.15(6.78)      11   41.89(22.47)                             100.00   -16.74 [-30.61, -2.87]
Subtotal (95% CI)        11                     11                                           100.00   -16.74 [-30.61, -2.87]
Test for heterogeneity: not applicable
Test for overall effect: Z = 2.37 (P = 0.02)

                                                           -100   -50    0    50   100
                                                      Favours active warm1   Favours active warm2
```
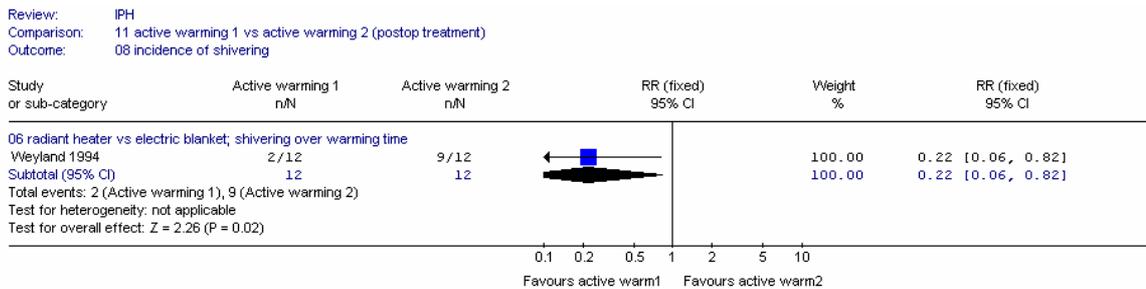
2. Incidence of shivering

Weyland (1994) reported shivering over the warming period and showed significantly less shivering for the radiant heater, although the confidence interval is wide. The risk of shivering is 1/5th that of the electric blanket, and the NNT is 2 (95% CI 2, 4) for a control group risk of 75%.

Figure 28: Incidence of shivering

Review: IPH
Comparison: 11 active warming 1 vs active warming 2 (postop treatment)
Outcome: 08 incidence of shivering

Study or sub-category	Active warming 1 n/N	Active warming 2 n/N	RR (fixed) 95% CI	Weight %	RR (fixed) 95% CI
06 radiant heater vs electric blanket; shivering over warming time					
Weyland 1994	2/12	9/12		100.00	0.22 [0.06, 0.82]
Subtotal (95% CI)	12	12		100.00	0.22 [0.06, 0.82]
Total events: 2 (Active warming 1), 9 (Active warming 2)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 2.26 (P = 0.02)					

0.1 0.2 0.5 1 2 5 10
Favours active warm1   Favours active warm2

B4. Forced air warming versus radiant heating

One indirect study in post-bypass patients compared two forced air warming devices (Bair Hugger® and Warm Touch®, setting and flow maximal for both) and two radiant heaters (Thermal Ceilings 1000W and self assembled 4 x 160W) (Bräuer 2004). Oesophageal temperatures were raised from below 35.5°C to above 37.5°C.

1. Rate of change of temperature

The study reported medians with 10th and 90th percentiles. These are reported in the table below. The authors reported no significant difference between any of these active interventions.

Table 3: Rate of change of temperature

Rate of change of temperature	
Type of warming device	Rate of oesophageal rewarming (°C / h) median (10%, 90% percentiles)
Forced air warming (Bair Hugger®)	0.9 (0.4, 1.3)
Forced air warming (Warm Touch®)	0.8 (0.4, 1.7)
Radiant heater (Thermal Ceilings)	0.6 (0.4,1.0)
Radiant heater (self assembled)	0.7 (0.5, 0.9)

C. Active warming versus thermal insulation

One study (Bredahl 1995) compared a radiant heater (500W) with a reflective blanket in 30 patients who had undergone combined general and regional anaesthesia. Both arms of the study had warmed IV fluids and the rectal temperature was measured.
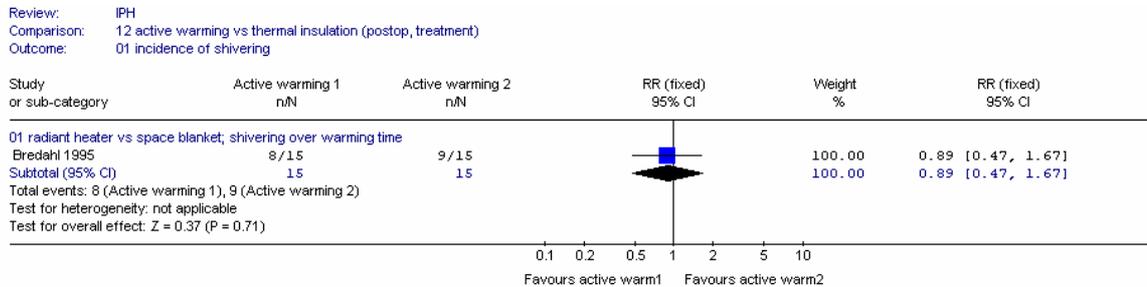
1. Core temperature after two hours in PACU

The Bredahl (1995) study reported the median and interquartile range at 15 minute intervals in a graphical form, and it is clear that the rate of change of median rectal temperature is greater for the radiant heating group compared to the reflective blanket group. The authors reported that the increase in median temperature over two hours was significantly greater for the radiant heating group (1.6°C in the radiant heater group; 0.9°C in the thermal insulation group; p<0.05).

2. Shivering

There was little difference in the number of patients shivering, either over the whole warming period (Figure 29) or at any time during it. The confidence interval is fairly wide.

Figure 29: Incidence of shivering

Review: IPH
Comparison: 12 active warming vs thermal insulation (postop, treatment)
Outcome: 01 incidence of shivering

Study or sub-category	Active warming 1 n/N	Active warming 2 n/N	RR (fixed) 95% CI	Weight %	RR (fixed) 95% CI
01 radiant heater vs space blanket; shivering over warming time					
Bredahl 1995	8/15	9/15		100.00	0.89 [0.47, 1.67]
Subtotal (95% CI)	15	15		100.00	0.89 [0.47, 1.67]
Total events: 8 (Active warming 1), 9 (Active warming 2)					
Test for heterogeneity: not applicable					
Test for overall effect: Z = 0.37 (P = 0.71)					

0.1 0.2 0.5 1 2 5 10
Favours active warm1   Favours active warm2

D. Thermal insulation versus usual care

One study with 144 patients (Hershey 1997) compared different types of thermal insulation as an adjunct to the use of two warmed thermal blankets. The study did not mention if the blankets were changed, and their warming temperature was not stated. Patients were randomised to one of the following three interventions:

- Two warmed thermal blankets (group 1; control group);
- Reflective blanket plus two warmed thermal blankets (group 2);
- Reflective blanket + reflective head covering + two warmed thermal blankets (group 3).

There were some reservations about the study: it measured oral temperatures, and the reflective blanket group (group 2) spent longer in theatre than either of the other groups (mean duration in theatre 184 minutes for control group; 233 minutes for group 2 and 201 minutes for group 3; SDs not given).

1. Time to raise the temperature

Hershey (1997) reported the time taken to reach 36.0°C from an initial mean temperature of 34.8°C or 35.0°C (Figure 30). There was little difference between interventions, and the addition of a reflective blanket and hat did not appear to help in reducing the time taken to reach 36.0°C.

Figure 30: Time to raise temperature
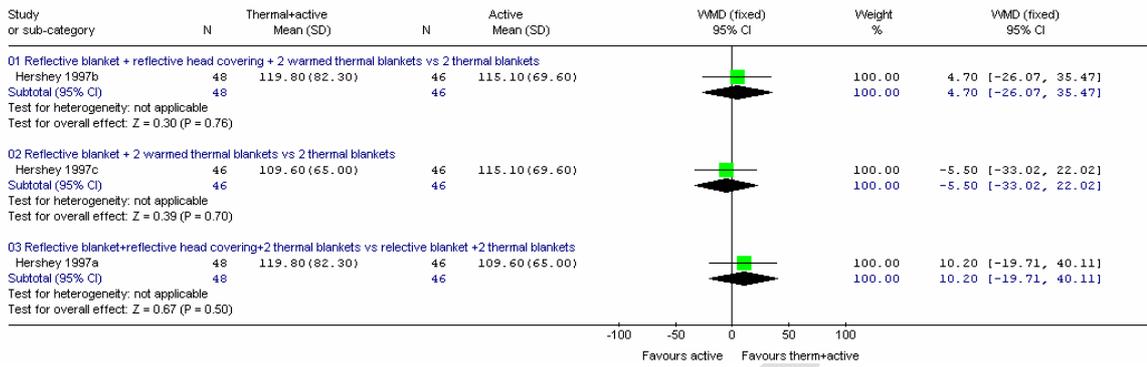
Summary of times to raise the temperature for various warming mechanisms

Table 4 summarises the times taken to raise the temperature for different warming mechanisms for all the trials. We note that these are observational data, usually in small numbers of patients, but are included as an indication of how long it takes to rewarm hypothermic patients in PACU and ICU.

1   **Table 4: Time to raise temperature for patients given forced air warming and radiant**
2   **heat**

Study	Location measured	Method	Initial temperature	Final temperature	Time
FORCED AIR WARMING					
Jackson (n=10)	**ICU**	**Core temperature**	**35.2°C (baseline)**	**36.1°C**	**60 min**
Lennon (n=15)	**PACU**	**Core oral temperature**	**35.0°C**	**36.0°C**	**45 min**
Guiffre (n=31)	**PACU**	**Time (oral T)**	**35.0°C**	**36.0°C**	**112.2 min (SD 52.3)**
RADIANT HEAT					
Weyland (n=10)	**ICU**	**time**	**35.0°C**	**37.0°C**	**median 100 min (range 76 to 143)**
35.0**°C** to 35.5**°C**					
FORCED AIR WARMING					
Lennon (n=15)	**PACU**	**Core oral temperature**	**35.2°C**	**35.8°C**	**15 min**
Alfonsi (n=9)	**PACU**	**Core temperature**	**35.2°C (baseline)**	**35.7°C**	**37 min**
Jackson (n=10)	**ICU**	**Core temperature**	**35.2°C (baseline)**	**35.5°C**	**30 min**
RADIANT HEAT					
Weyland (n=10)	**ICU**	**time**	**35.0°C**	**35.5°C**	**25.1 min (SD 8.6)**
Bredahl	**PACU**	**Median core**	**median**	**median**	**30 min**

| (n=15) | temperature | 34.9°C | 35.3°C |

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35.5°C to 36.0°C					
FORCED AIR WARMING					
Jackson (n=10)	ICU	Core temperature	35.5°C	36.1°C	30 min
Lennon (n=15)	PACU	Core oral temperature	35.8°C	36.0°C	15 min
RADIANT HEAT					
Weyland (n=10)	ICU	time	35.5°C	36.0°C	23.3 min (SD 5.1)
Bredahl (n=15)	PACU	Median core temperature	median 35.3°C	median 36.0°C	45 min
36.0°C to 36.5°C					
FORCED AIR WARMING					
Jackson (n=10)	ICU	Core temperature	36.1°C	36.8°C	60 min
RADIANT HEAT					
Weyland (n=10)	ICU	time	35.5°C	36.0°C	25.2 min (SD 6.8)
Bredahl (n=15)	PACU	Median core temperature	median 36.0°C	median 36.4°C	45 min

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