NATIONAL INSTITUTE FOR HEALTH AND CLINICAL EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedure overview of thoracoscopically assisted mitral valve surgery

Thoracoscopically assisted mitral valve surgery involves the repair of a defective valve through one or more small incisions between the ribs rather than one large incision through the breastbone (sternum), and using a camera to visualise the procedure. The patient is connected to a heart–lung machine, which temporarily takes over the function of the heart and lungs during the procedure. Robotic assistance can also be used during the procedure.

Introduction

This overview has been prepared to assist members of the Interventional Procedures Advisory Committee (IPAC) in making recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the medical literature and specialist opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This overview was prepared in April 2007.

Procedure name

- Thoracoscopically assisted minimally invasive mitral valve surgery

Specialty societies

- Society of Cardiothoracic Surgeons of Great Britain and Ireland
- British Cardiovascular Intervention Society
- Society of Clinical Perfusionists

Description

Indications

Mitral valve disease (encompassing, stenosis, regurgitation, or mixed (stenotic and regurgitant) disease) that requires surgical repair or replacement.

Mitral stenosis is a structural abnormality of the valve causing a narrowing of the mitral passage which obstructs blood flow from the left atrium to the left ventricle. Mitral stenosis is a progressive life-long disease that is commonly caused by rheumatic fever. The onset of symptoms may be several years, or even decades, after the occurrence of rheumatic fever. Symptoms of mitral stenosis include dyspnoea, fatigue, palpitations and haemoptysis. If untreated, patients with mitral stenosis can die from congestive heart failure.

Mitral valve regurgitation is characterised by backward flow of blood from the left ventricle to the left atrium during systole. It causes the left ventricle to become enlarged because of the additional workload required to maintain normal blood flow. Left untreated, moderate to severe mitral regurgitation can cause death due to congestive heart failure.

Mitral valve prolapse is a structural or functional abnormality of the valve which can cause mitral regurgitation. Mitral valve prolapse is the most common disorder affecting the cardiac valves and can be caused by myxomatous degeneration, ruptured chordae (from trauma or myocardial infarction), rheumatic heart disease, coronary heart disease or connective tissue disorder.

All types of mitral valve disease are commonly associated with chronic atrial fibrillation.

Current treatment and alternatives

Treatment options for mitral stenosis include medical management and surgical repair or replacement of the valve. Medical therapy aims to reduce the risk of congestive heart failure, and to control co-existing atrial fibrillation and the associated risk of thromboemobolic stroke.

Mitral valve repair for stenosis can be attempted by percutaneous mitral balloon valvotomy or surgical commissurotomy. In percutaneous valvotomy (also termed balloon valvuloplasty or balloon commissurotomy), a balloon-catheter is threaded into the circulation and inflated across the mitral valve to separate the fused valve leaflets and relieve the obstruction. In surgical commissurotomy, an incision is made to separate the abnormally joined valve leaflets.

Mitral valve replacement is required if the stenosis is too severe or the repair has failed.

Surgical procedures for mitral regurgitation include repair and replacement of the valve. During repair, the leaking section of valve is removed, or repair made to broken cords that support the valve. In addition a ring may be placed around the base (annulus) of the valve if it is found to be too large.

Mitral valve replacement is required if the repair has failed or is not possible.

Traditionally, surgical procedures for repairing or replacing the mitral valve are performed through a median sternotomy, which is a full incision of the breastbone. This approach allows complete access to the heart but recovery may be slower due to discomfort following sternotomy.

What the procedure involves

This review relates to mitral valve surgery procedures which use thoracoscopic visualisation of the operative field for at least part of the operation.

Thoracoscopically assisted mitral valve surgery is carried out under general anaesthesia. Cardiopulmonary bypass (CPB) is established using peripheral cannulation where catheters are inserted into the major blood vessels of the thigh and the neck and threaded to the heart. To occlude the aorta, either inflation of an endoaortic balloon or placement of a transthoracic aortic cross-clamp is used. Cardioplegic solution is administered to achieve cardiac arrest and myocardial protection.

A number of small incisions are made in the chest wall between the ribs, without bone separation. In the totally thoracoscopic version of this procedure, mitral valve surgery is carried out entirely under thoracoscopic (also called, indirect, secondary, or 2D) vision. However, hybrid approaches using both direct and thoracoscopic visualisation of the operative field may be used.

Thoracoscopically assisted mitral valve surgery can also be carried out with computer assistance (this is also called robotically assisted surgery).

This review does not include procedures that are performed via a small incision through the chest wall and without thoracoscopic assistance.

Efficacy

The Specialist Advisers listed key efficacy outcomes as survival, success of the planned operation in repairing or replacing the valve, long-term durability of repair or replacement, postoperative pain, operating time, CPB time, duration of intensive care, length of hospital stay, return to full activity, requirement for blood transfusion, cosmetic results and unplanned reoperation.

The efficacy evidence is based on eight case series.

Conversion to sternotomy

Five of the eight studies included in this overview reported rates of conversion to sternotomy. In a case series of 449 patients, 4 (1%) required sternotomy because of aortic dissection (n=3) and left ventricular wall injury (n=1).[1] This study included patients who had a transthoracic clamp for aortic occlusion or Port-Access endoaortic balloon occlusion, and all conversions to sternotomy were in the latter group. No conversions to sternotomy were required in another case series of 120 patients, half of whom underwent each of these two clamp techniques.[2]

In another case series of 306 patients who underwent the Port-Access technique for mitral valve surgery, a sternotomy was required in 6 patients (2%) because of aortic dissection (n = 2), inadequate CPB flow (n = 3) and perforation of the iliac artery (n = 1).[3]

A case series of data from the Port-Access International Registry, which included 1059 patients who underwent mitral valve surgery and a further 252 who underwent Port-Access aortic valve surgery, reported 50 conversions to sternotomy overall (3.8%). The most commonly reported reasons for these were “vascular injury” (n = 6), “patient anatomy” (n = 4) or “poor visualisation” (n = 4).[4]

Conversion to sternotomy was required in 5 procedures and to thoracotomy with rib spreading in 1 procedure in a study of 127 patients who underwent robotic mitral valve surgery. The reasons were: one case each of insufficient venous return, ruptured breast implant, failure of the vision system, insufficient working space, femoral arterial disease and marked aortic tortuosity.[5]

Postoperative valve function

In the case series of 449 patients, regular valve function was seen in 97% (318/327) of mitral valve repairs intraoperatively, and a good functional result was seen in all patients who underwent mitral valve replacement (n=122) [1].

A case series of 430 patients reported that postoperative regurgitation (measured on a scale from 0 = no regurgitation to 4 = severe regurgitation) was 0.4 (mean follow-up 38 months), compared with 3.1 preoperatively.[6] In this study, all patients who had valve repair (n = 62) had trivial or no regurgitation at discharge, and all replaced valves were functioning normally (n = 368).

In the case series of 306 patients, of whom 215 underwent valve repair, the median grade of preoperative mitral regurgitation was 4.[3] At follow-up (mean 15 months), 67% (145/215) had grade 0 regurgitation, 26% (56/215) had grade 1, and 7% (14/215) had grade 2 or 3.

In the case series of 127 patients, 95% (121) had grade 4 regurgitation before the procedure. Of the 114 who underwent mitral repair, 91% (104) had grade 0 regurgitation immediately after surgery, and 89% (87/98) had grade 0 regurgitation at a mean follow-up of 8.4 months.[5]

Approximately 76% (91/120) of patients in another case series had grade 0 regurgitation at discharge.[2]

Heart failure functional class
Three studies measured heart failure function using the New York Heart Association (NYHA) scale where class 1 indicates no limitation in daily activity and class 4 indicates severe limitations even at rest. In the case series of 430 patients, preoperative NYHA class improved from 2.8 before surgery to 1.4 at mean follow-up of 38 months.[6] In a study of 127 patients, mean NYHA class improved from 2.5 before surgery to 1.0 at mean follow-up of 14 months.[5] The study with 120 patients reported that 85% were in NYHA class 1 at 3 months' follow-up.[2]

Operating time
Average aortic occlusion times ranged from 51[6] to 146 minutes.[5] Average CPB time ranged from 90[6] to 182 minutes.[5]

In the case series comparing video-assisted and robotically assisted surgery, both aortic occlusion time and CPB time were longer in the robotic group.[7]

In the study comparing 60 endoaortic clamp procedures and 60 transthoracic clamp procedures, mean aortic occlusion times and mean CPB times were longer for the endoaortic clamp technique (89 vs 78 minutes, respectively, for aortic occlusion; 138 vs 120 minutes, respectively for CPB time).[2]

Length of stay
Average length of stay in intensive care ranged from 22 hours[4] to 41 hours[3] in the eight case series. Average length of hospital stay ranged from 4.5[5] to 11 days.[1]

In the case series of 449 patients, hospital stay (and operating times) was similar between the Port-Access endoclamp group and the transthoracic clamp group. [1]

Safety

The Specialist Advisers listed potential adverse events as including: death, aortic dissection, myocardial infarction, prolonged cross-clamp and CPB times leading to poor myocardial preservation, maintenance of satisfactory cardioplegia, compromised quality of mitral valve repair, possibly requiring 'redo' surgery, damage to peripheral vessels due to cannulation, peripheral vascular disease, paravalvular leakage, stroke, perioperative bleeding, lung injury, heart failure and renal failure.

The safety evidence is based on eight case series.

Mortality
Four studies reported hospital mortality of 0/120 patients[2], 0.8% (1/127)[5], 4% (39/1059) [4] and 4% (18/449) [1] in patients who underwent minimally invasive techniques. In the latter study of 449 patients, there were 11 hospital deaths in the Port-Access endoclamp group (n=209; 5%) and 7 deaths in the transthoracic clamp group (n=226; 3%).

Thirty-day mortality was reported as 2% (9/441)[7], 0.2% (1/430)[6], and 1% (3/306)[3] of patients in a further three case series.

New-onset atrial fibrillation
This was the most common perioperative complication overall in the eight case series, occurring in approximately 10% of 1059 patients in the Port-Access Registry study,[4] and reported in 3% (12/430),[6] 17% (absolute numbers not reported),[3] 17% (20/120)[2] and 18% (22/121)[5] of patients in four further studies. Arrhythmias were reported in 20% (88) of a case series of 449 patients.[1]

Bleeding and transfusion
Five studies reported that bleeding requiring reoperation occurred in 0.9% (4/430),[6] 3% (3/121),[5] 4% (17/441),[7] 5% (48/1059),[4] and 8% (26/306)[3] of patients.

In one study, blood transfusion was required in 30% of 341 patients who underwent video-assisted operations and 15% of 100 patients who underwent robot-assisted operations.[7] Another study reported that 58% of patients undergoing mitral valve repair and 66% of those undergoing mitral valve replacement required transfusion.[4]

In the case series of 449 patients, bleeding was reported in 7% of patients (14/209) who underwent Port-Access endoaortic clamp procedures and in 5% of patients (11/226) who underwent the transthoracic clamp procedures.[1] In the case series of 120 patients who underwent endoaortic clamp occlusion (n = 60) and or transthoracic clamp occlusion (n = 60), exploration for bleeding was required in 10% and 2% of patients, respectively.[2]

Neurological complications
In the case series of 449 patients, neurological complications (stroke and transient hemiplegia) occurred more frequently in patients undergoing Port-Access endoaortic clamp than in those undergoing transthoracic clamp procedures: 8% (17/209) and 2% (4/226), respectively ($p < 0.05$).[1]

Aortic dissection
One study reported aortic dissection in 3 patients who underwent an endoaortic clamp procedure (n = 209) and none in those who had a transthoracic clamp procedure (n = 226).[1] Aortic dissection was reported in 2 patients in another case series of 306 patients who underwent the Port-Access technique with endoaortic balloon occlusion (both of whom required conversion to sternotomy).[3]

Literature review

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to thoracoscopically assisted minimally invasive mitral valve surgery.

Searches were conducted via the following databases, covering the period from their commencement to 27 April 2007: Medline, PreMedline, EMBASE, Cochrane Library and other databases. Trial registries and the Internet were also searched. No language restriction was applied to the searches. (See Appendix C for details of search strategy.)

The following selection criteria (Table 1) were applied to the abstracts identified by the literature search. Where these criteria could not be determined from the abstracts the full paper was retrieved.

Table 1 Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	Clinical studies were included. Emphasis was placed on identifying good quality studies. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, or laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising methodology.
Patient	Patients with mitral valve disease
Intervention/test	Thoracoscopically assisted mitral valve surgery
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

List of studies included in the overview

This overview is based on seven case series.

Other studies that were considered to be relevant to the procedure but were not included in the main extraction table (Table 2) are listed in Appendix A.

Existing reviews on this procedure

No published systematic reviews were identified at the time of the literature search.

Related NICE guidance

NICE has not published any guidance related to this procedure.

Table 2 Summary of key efficacy and safety findings on thoracoscopically assisted mitral valve surgery

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

<table>
<tr><th>Study details</th><th>Key efficacy findings</th><th>Key safety findings</th><th>Comments</th></tr>
<tr>
<td>
Glower DD (2000)[4]

Case series (Port-Access Registry)
International (104 institutions)
Study period: July 1997–Aug 1999

n = 1059 (568 replacements, 491 repairs)
(plus data for 252 aortic procedures)

Population: Patients undergoing isolated MV surgery
<table>
<tr><th></th><th>Repair</th><th>Replacement</th></tr>
<tr><td>Mean age</td><td>57 years</td><td>60 years</td></tr>
<tr><td>Male</td><td>66%</td><td>39%</td></tr>
<tr><td>Reoperation</td><td>8%</td><td>23%</td></tr>
<tr><td>MV insufficiency grade 3 or 4</td><td>75%</td><td>76%</td></tr>
<tr><td>NYHA class 3 or 4</td><td>53%</td><td>75%</td></tr>
</table>
Exclusions: age > 85 years, emergent operation, life expectancy < 2 years, significant femoral, iliac or aortic arterial disease.

Technique: Port-Access System
Incision: 6cm right anterior/lateral thoracotomy
Visualisation: videoscope placed through a 10mm port (as described in a referenced article)
CPB: EndoCPB or EndoDirect system (Heartport, USA)
Aortic occlusion: endovascular aortic clamp (as described in a referenced article)

FU (total group): 23% to discharge, 77% to 30 days

Conflict of interest: Registry part-funded by manufacturer (Heartport).
</td>
<td>
Conversion to sternotomy (all patients): 3.8% (50/1311)
Reasons (as recorded on data entry form):

Vascular injury = 6
Patient anatomy = 4
Poor visualisation = 4
Inability to place system catheter = 1
Inadequate CPB = 1
Calcific aorta on palpation = 1
Other = 4

Operative and hospital outcomes
<table>
<tr><th></th><th>MV repair</th><th>MV replacement</th></tr>
<tr><td>Median aortic occlusion time (min)</td><td>92 (75-115)</td><td>89 (70-116)</td></tr>
<tr><td>Median CPB time (min)</td><td>127 (110-158)</td><td>137 (108-180)</td></tr>
<tr><td>Median ICU stay (hours)</td><td>22 (17-28)</td><td>23 (19-48)</td></tr>
</table>
Return to activity

81% of MV repair patients and 67% of MV replacement patients were walking within 48 hours of surgery

</td>
<td>
Operative mortality: 3.7% (39/1059)
(1.6% MV-repair group; 5.5% MV-replacement group)
Causes of death (MV-repair and MV-replacement groups combined; numbers not stated):

Cardiac = 2.5%
Multisystem failure = 1.8%
Neurologic = 0.6%
Vascular = 0.5%
Renal failure = 0.4%
Pulmonary = 0.4%
Infection = 0.2%
Other = 0.7%

Perioperative complications
<table>
<tr><th></th><th>MV repair (n=491)</th><th>MV replacement (n=568)</th></tr>
<tr><td>New-onset atrial fibrillation</td><td>10.4%</td><td>10.0%</td></tr>
<tr><td>Pleural effusion</td><td>4.5%</td><td>4.0%</td></tr>
<tr><td>Reoperation for bleeding</td><td>2.6%</td><td>6.2%</td></tr>
<tr><td>Renal failure</td><td>2.1%</td><td>3.3%</td></tr>
<tr><td>Stroke</td><td>2.6%</td><td>2.8%</td></tr>
<tr><td>Multisystem failure</td><td>0.6%</td><td>2.6%</td></tr>
<tr><td>Paravalvular leak</td><td>0.6%</td><td>0.5%</td></tr>
<tr><td>Myocardial infarction</td><td>0.4%</td><td>0.2%</td></tr>
</table>
Readmission within 30 days: 8.4% MV-repair group; 7.5% MV-replacement group
Intra/postoperative transfusion: 58% MV-repair group; 66% MV-replacement group
</td>
<td></td>
</tr>
</table>

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

<table>
<tr><th>Study details</th><th>Key efficacy findings</th><th>Key safety findings</th><th>Comments</th></tr>
<tr>
<td>Onnasch JF (2001)[1]

Case series
Germany
Study period: 1996–2001

n = 449 (122 replacements, 327 repairs)

Population: Patients undergoing MV surgery
Mean age: 59 years; male: 47%
Reoperation (previous cardiac surgery): 9%

Indications:
Mitral regurgitation ≥ grade 3: 87%
NYHA class 2 or 3: 79%

Technique:
Incision: mean 4.3cm right lateral minithoracotomy
Visualisation: videoscopic guidance via voice-controlled robotic arm used in 366 patients; telemanipulator system used in 23 patients
CPB: femoral or femoral-axillary cannulation
Aortic occlusion: Endoaortic balloon occlusion used in first 209 patients (+ all reoperations); transthoracic aortic clamp in latter 226 patients.

Mean FU: 11 months

Conflict of interest: None stated</td>
<td>Conversion to sternotomy: 1% (4/449)
• Port-access endoclamp: 2% (4/209) (aortic dissection = 3, left ventricular wall injury = 1)
• Transthoracic clamp: 0

Operative and hospital outcomes (all procedures)
• Mean aortic occlusion time 67 mins (SD 29)
• Mean CPB time: 125 mins (SD 42)
• Median ICU stay: 1 day (range 0.5 to 58)
• Median hospital stay: 11 days (range 2 to 60)

No statistically significant differences between the groups.

Intraoperative echocardiography
• Regular valve function was seen in 97% (318/327) of MV-repair group: 9 patients with failed repairs had subsequent conversion to valve replacement.
• A good functional result was seen in all patients who had MV replacement.</td>
<td>Hospital mortality: 4.1% (18/435)
• Port-access endoclamp: 5.3% (11/209)
• Transthoracic clamp: 3.1% (7/226)

Postoperative complications
<table>
<tr><th></th><th>Port-access endoclamp</th><th>Trans-thoracic clamp</th></tr>
<tr><td>Arrhythmias</td><td>22% (45/209)</td><td>19% (43/226)</td></tr>
<tr><td>Pulmonary</td><td>10% (21/209)</td><td>6% (14/226)</td></tr>
<tr><td>Bleeding</td><td>7% (14/209)</td><td>5% (11/226)</td></tr>
<tr><td>Neurological (stroke, transient hemiplegia)*</td><td>8% (17/209)</td><td>2% (4/226)</td></tr>
<tr><td>Renal failure</td><td>2% (4/209)</td><td>2% (4/226)</td></tr>
<tr><td>Low cardiac output</td><td>2% (4/209)</td><td>0.5% (1/226)</td></tr>
<tr><td>Aortic dissection</td><td>1% (3/209)</td><td>0</td></tr>
</table>
* $p < 0.05$ between groups.

Reoperation: 7% (23/312 patients followed up, period not stated)
Reasons for reoperation:
• Regurgitation > grade 2 (n=12)
• Paravalvular leakage (n=4)
• Acute torn ring (n=3)
• Acute endocarditis (n=2)
• Progressive heart failure (n=2)</td>
<td>The reason for discrepancy between total population (n = 449) and number of patients for whom outcomes are reported (n = 435) is not clear.

The authors state that complications in Port-Access endoclamp group occurred in the early phase of the procedure; no more aortic dissections were seen after a new design of endoclamp was introduced.

Neurological complications in the Port-Access endoclamp group decreased after the introduction of transcranial Doppler monitoring for balloon migration.</td>
</tr>
</table>

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

<table>
<tr><th>Study details</th><th>Key efficacy findings</th><th>Key safety findings</th><th>Comments</th></tr>
<tr>
<td>Chitwood WR (2005)[7]

Case series
USA
Study period: 1996–2004

n = 441 (341 video-assisted procedures consisting of 92 replacements and 249 repairs, plus 100 robot assisted procedures – all repairs)

Population: Patients undergoing MV surgery

Mean age: 60 years (video-assisted), 57 years (robot-assisted)
Male: Not reported

Technique:
Incision: 5cm right minithoracotomy
Visualisation: either voice-controlled camera arm and robotic telemanipulation or two-dimensional endoscopic camera
CPB: peripheral femoral cannulation (central aortic cannulation used in patients with peripheral atherosclerosis)
Aortic occlusion: transthoracic clamp

Mean FU: 11 months

Conflict of interest: None stated</td>
<td>Operative and hospital outcomes
<table>
<tr><th></th><th>Video-assisted</th><th>Robot-assisted</th></tr>
<tr><td>Mean aortic occlusion time (min)</td><td>87 (SD 2)</td><td>126 (SD 3)</td></tr>
<tr><td>Mean CPB time (min)</td><td>140 (SD 3)</td><td>162 (SD 4)</td></tr>
<tr><td>Mean hospital stay (days)</td><td>7 (SD 0.5)</td><td>5 (SD 0.8)</td></tr>
</table>
</td>
<td>30-day mortality
• Video-assisted: 2.3% (8/341)
Causes of deaths not stated
• Robot-assisted: 1.0% (1/100)
Patient had a stroke at reoperation
(A second death related to respiratory failure and bowel ischaemia occurred 6 weeks after surgery).

Complications
<table>
<tr><th></th><th>Video-assisted</th><th>Robot-assisted</th></tr>
<tr><td>Bleeding requiring reexploration</td><td>4% (15/341)</td><td>2% (2/100)</td></tr>
<tr><td>Blood transfusion</td><td>30% (101/341)</td><td>15% (15/100)</td></tr>
</table>
Reoperation for failed valve repair
• Video-assisted: 1.8% (6/341)
• Robot-assisted: 2.0% (2/100)</td>
<td>Authors state that learning curve was evident as operating times decreased significantly from first 50 to second 50 robotic procedures ($p < 0.01$).</td>
</tr>
</table>

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

<table>
<tr><th>Study details</th><th>Key efficacy findings</th><th>Key safety findings</th><th>Comments</th></tr>
<tr>
<td>Mishra YK (2005)[6]

Case series
India
Study period: Sept 1997–Dec 2004

n = 430 (368 replacements, 62 repairs)
(plus 336 atrial septal defect closures)

Population: Patients undergoing MV surgery
Mean age: 42 years (range 14–76)
Male: 33%
Reoperation: 21% (92/430)

Indications:
Mitral insufficiency: 67% (288/430)
Mitral stenosis: 33% (142/430)
Severe preoperative regurgitation: 4% (18/430)
Mild-to-moderate regurgitation: 10% (42/430)

Technique: Port-Access
Incision: 5-6cm anterolateral thoracotomy through 4th intercostal space
Visualisation: direct vision for all procedures; video-assistance using endoscope attached to a voice-controlled robotic arm (AESOP) also used for 250 procedures
CPB: peripheral (femoral) cannulation.
Aortic occlusion: endoaortic clamp (n = 72); transthoracic clamp (n = 358).

Mean FU: 38 months (SD 6 months)

Conflict of interest: None stated</td>
<td>Conversion to sternotomy: 0

Operative and hospital outcomes
• Mean aortic occlusion time: 51 mins (SD 29)
• Mean CPB time: 90 mins (SD 48)
• Mean ICU stay: 26 hours (range 18–38)
• Mean hospital stay: 7 days (range 5–17)

Functional and echocardiographic outcomes at FU (mean 38 months)
<table>
<tr><th></th><th>Pre-operative</th><th>Post-operative</th></tr>
<tr><td>NYHA functional class</td><td>2.8 (SD 0.4)</td><td>1.4 (SD 0.6)</td></tr>
<tr><td>Regurgitation (scale from 0 = no regurgitation to 4 = severe regurgitation)</td><td>3.1 (SD 0.3)</td><td>0.4 (SD 0.3)</td></tr>
</table>
Other
At discharge, all patients with MV repair had none or trivial regurgitation and all replaced valves were functioning normally.

At FU, all patients except 4 had improved activity levels compared with preoperative status.</td>
<td>30-day mortality 0.2% (1/430)
• Patient died on day 12 from upper GI bleeding

One late death from to prosthetic valve endocarditis

Perioperative complications
• Atrial fibrillation: 2.8% (12/430)
• Bleeding requiring reexploration: 0.9% (4/430)
• Hemiparesis with full resolution: 0.5% (2/430)
• Heartblock: 0.5% (2/430)
• Renal failure: 0.5% (2/430)

Reoperation
Required for anti-coagulation-related bleeding in 2 patients (0.5%)</td>
<td>Not all were isolated MV repair procedures - some were mixed procedures i.e. MV repair or replacement plus tricuspid valve repair.

The study population is younger than in other studies which could explain the lower complication rates and mortality.

Both endoarotic and transthoracic clamps were used but results are not reported separately for each technique.

<u>NYHA classification</u>
Assess functional capacity of cardiac patients From I = no limitation in daily physical activity, to IV = severe limitations even at rest</td>
</tr>
</table>

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

<table>
<tr><th>Study details</th><th>Key efficacy findings</th><th>Key safety findings</th><th>Comments</th></tr>
<tr>
<td>Casselman FP (2003)[3]

Case series
Belgium
Study period: 1997–2002

n = 306 (80 replacements, 226 repairs)

Population: Patients undergoing MV surgery
Mean age: 62 years
Male: 53%
Reoperation after previous commissurotomy: 0.7% (2/306)

Indications:
MV-replacement group: Median preoperative regurgitation = grade 4
MV-repair group: Median stenosis = 12.6mmHg

Technique: Port-Access
Incision: 4-6cm ‘working port’ in right inframammary groove, 4th intercostal space
Visualisation: Thoracoscopic visualisation through a separate 5mm port
CPB: peripheral (femoral-femoral) cannulation.
Aortic occlusion: endoaortic balloon occlusion and EndoClamp

Mean FU: 20 months (range 0–60)

Conflict of interest: None stated</td>
<td>Conversion to sternotomy: 2% (6/306)
(MV repair: 3, MV replacement: 3)
Reasons:
• Aortic dissection = 2
• Inadequate CPB flow = 3
• Iliac artery perforation = 1

Operative and hospital outcomes
<table>
<tr><th></th><th>MV repair</th><th>MV replacement</th></tr>
<tr><td>Median aortic occlusion time (min)</td><td>91 (24-160)</td><td>102 (60-239)</td></tr>
<tr><td>Median CPB time (min)</td><td>132 (74-246)</td><td>146 (94-359)</td></tr>
<tr><td>Mean ICU stay (hours)</td><td colspan="2">41 (SD 56)</td></tr>
<tr><td>Mean hospital stay (days)</td><td colspan="2">9 (SD 6)</td></tr>
</table>
Echocardiographic FU
(mean 15 months, range 0-55 months)
<u>MV repair (n=215)</u>
• Degree of regurgitation:
- grade 0 = 67% (145/215)
- grade 1+ = 26% (56/215)
- grade 2+ = 6% (12/215)
- grade 3+ = 1% (2/215)
<u>MV replacement (n=69)</u>
• Small paravalvular leak = 6% (4/69)

Patient satisfaction
• Minimal/no procedure-related pain = 94%
• Routine activity within 4 weeks = 46%
• Routine activity within 8 weeks = 71%</td>
<td>30-day mortality (early deaths): 1% (3/306)
Causes of death:
• Aortic dissection during procedure
• Low cardiac output syndrome on day 5 (sternotomy patient)
• Disseminated intravascular coagulation on day 4 after reinterventions for bleeding

Late deaths (mean FU 20 months): 2.0% (6/306)
Causes of death:
• Sudden death
• After cholecystectomy
• Pneumonia
• Small bowel perforation
• Stroke
• Sternitis (in a converted patient)

Postoperative complications
<table>
<tr><th></th><th>MV repair (n=226)</th><th>MV replacement (n=80)</th></tr>
<tr><td>New-onset atrial fibrillation</td><td>17.7%</td><td>15.0%</td></tr>
<tr><td>Groin lymphocoele</td><td>5.3%</td><td>2.5%</td></tr>
<tr><td>Subcutaneous emphysema</td><td>3.5%</td><td>1.3%</td></tr>
<tr><td>Renal insufficiency</td><td>2.2%</td><td>3.8%</td></tr>
<tr><td>Pneumonia</td><td>1.8%</td><td>5.0%</td></tr>
<tr><td>Pacemaker implantation</td><td>2.2%</td><td>2.5%</td></tr>
<tr><td>Pleural effusion</td><td>1.8%</td><td>2.5%</td></tr>
</table>
</td>
<td>Not all were isolated MV repair procedures. Some mixed procedures i.e. repair or replacement plus tricuspid annuloplasty or arrhythmia ablation.</td>
</tr>
</table>

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

<table>
<tr><th>Study details</th><th>Key efficacy findings</th><th>Key safety findings</th><th>Comments</th></tr>
<tr>
<td></td>
<td>

Extremely satisfied with cosmesis = 99%
Would choose procedure again = 94%

</td>
<td>
<table>
<tr><td>Myocardial infarction</td><td>0.4%</td><td>1.3%</td></tr>
<tr><td>Stroke</td><td>0.4%</td><td>0</td></tr>
</table>

Aggressive postoperative reintervention for suspected bleeding: 8.5% (26/306)

Reoperation: 3.6% (11/306)
1 early reoperation (patient died postoperative day 5)
10 late reoperations (FU period not stated)
These patients required subsequent (late) sternotomy to replace the MV.

Reasons for late reoperation:
<table>
<tr><th></th><th>MV repair</th><th>MV replacement</th></tr>
<tr><td>New endocarditis</td><td>4</td><td>1</td></tr>
<tr><td>Regurgitation</td><td>2</td><td>0</td></tr>
<tr><td>Pannus overgrowth</td><td>0</td><td>1</td></tr>
<tr><td>Valve thrombosis</td><td>0</td><td>1</td></tr>
<tr><td>Paravalvular leak</td><td>0</td><td>1</td></tr>
</table>
</td>
<td></td>
</tr>
</table>

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

<table>
<tr><th>Study details</th><th>Key efficacy findings</th><th>Key safety findings</th><th>Comments</th></tr>
<tr>
<td>Murphy DA (2006)[5]

Case series
U.S.A.
Study period: Dec 2002–Nov 2005

n = 127 (7 replacements, 114 repairs of 121 patients whose procedures were able to be performed endoscopically in the end)

Population: patients undergoing robotic MV surgery
Mean age: 54 years (range 21-78)
Male: 58%

Indications:
NYHA class 1 = 11/127
NYHA class 2 = 55/127
NYHA class 3 = 45/127
NYHA class 4 = 16/127

Technique:
Incision: 3-4cm service port in 4th intercostal space
Visualisation: endoscope inserted through 1.2cm port in 4th or 5th intercostal space lateral to service port
CPB: femoral cannulation for Port-Access
Aortic occlusion: technique not specified

Mean FU: 14 months (SD 9 months)

Conflict of interest: None stated</td>
<td>Conversion to sternotomy (5) or thoracotomy with rib-spreading (1): 5% (6/127)
Reasons (1 each):
• Ruptured breast implant
• Insufficient venous return
• Vision system failure
• Femoral arterial disease
• Insufficient working space
• Marked aortic tortuosity

Operative and hospital outcomes
<table>
<tr><th></th><th>MV repair</th><th>MV replacement</th></tr>
<tr><td>Mean aortic occlusion time (min)</td><td>102 (47-182)</td><td>146 (126-183)</td></tr>
<tr><td>Mean CPB time (min)</td><td>131 (72-234)</td><td>182 (154-236)</td></tr>
<tr><td>ICU stay < 24 hours</td><td>94%</td><td>57%</td></tr>
<tr><td>Mean hospital stay (days)</td><td>4.5 (range 2-48)</td><td>9.1 (range 4-25)</td></tr>
</table>
</td>
<td>Hospital mortality: 0.8% (1/127)
Patient had a stroke after sternotomy and died on postoperative day 48.

One late death 2 months after surgery (patient had mild regurgitation, autopsy showed intact MV repair).

Complications (n=121 patients treated endoscopically)
Perioperative
• Blood transfusion: 31% (37/121)
• Reexploration for bleeding: 2.5% (3/121)

Postoperative
• New-onset atrial fibrillation: 18% (22/121)
• Groin lymphocoele: 2% (2/121)
• Stroke: 2% (2/121)
• Right pleural effusion: 2% (2/121)
• Pneumonitis: 2% (2/121)
• Ventilation > 24 hours: 2% (2/121)
• Prolonged air leak: 1% (1/121)
• Transient renal dysfunction: 1% (1/121)
• Groin wound cellulitis: 1% (1/121)
• Paravalvular leak: 1% (1/121) – occurred 6 weeks after surgery: repair successfully via minithoracotomy.

Re-admission within 30 days: 4% (5/127)
• Atrial fibrillation (3)
• Groin wound cellulitis (1)
• GI haemorrhage (1)</td>
<td></td>
</tr>
</table>

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

Study details	Key efficacy findings	Key safety findings	Comments

Echocardiographic FU – regurgitation grade

	Preop (n=127)	Postop (n=114 MV repairs)	Follow-up (n=98 MV repairs, mean FU 8.4 mos)
4+	95% (121/127)		
3+	3% (4/127)		
2+	1% (2/127)	1% (1/114)	3% (3/98)
1+		8% (9/114)	8% (8/98)
0		91% (104/114)	89% (87/98)

NYHA functional class

	Preop (n=127)	Postop (n=119 endoscopic patients surviving at FU; mean 14 months)
1	9% (11/127)	92% (109/119)
2	43% (55/127)	7% (8/119)
3	35% (45/127)	2% (2/119)
4	13% (16/127)	0

Return to activity
88% of patients returned to full activity within 3 weeks.

Abbreviations used: CPB, cardiopulmonary bypass; FU, follow-up; GI, gastrointestinal; ICU, intensive care unit; MV, mitral valve; NYHA, New York Heart Association functional class; SD, standard deviation; TEE, transesophageal echocardiograph

Study details

Reichenspurner H (2005)[2]

Case series
Germany
Study period: May 1997–Nov 2002

n = 120 (39 replacements, 81 repairs)

Population: consecutive patients undergoing combined or isolated MV surgery
Mean age: 62 years (range SD 10.5)
Male: 29%

Indications:
Isolated valve insufficiency: 68% (81/120)
Combined mitral valve disease: 33% (39/120)

Technique
Incision: 4-8cm, right inframammary groove, 4th intercostal space
Visualisation: thoracoscopic port inserted cranially of main incision; two- or three-dimensional video-assistance and 75% were also assisted by a robotic camera-arm
CPB: femoro-femoral cannulation
Aortic occlusion: endoaortic balloon inserted under TEE guidance for first 60 patients (Port-Access technique) and transthoracic clamp for last 60 patients.

Mean FU: 3 months

Conflict of interest: None stated

Key efficacy findings

Conversion to sternotomy
None in either group

Operative and hospital outcomes

	Port-access endoclamp	Trans-thoracic clamp
Mean aortic occlusion time (min)	89 (SD 69)	78 (SD 65)
Mean CPB time (min)	138 (SD 29)	120 (SD 25)
Mean ICU stay (days)	1.5 (SD 2.1)	1.6 (SD 2.5)
Mean postoperative hospital stay (days)	9 (SD 10.5)	9.2 (SD 9.7)

Echocardiographic outcomes at discharge

Regurgitation grade	Port-Access endoclamp	Trans-thoracic clamp
0	75% (45/60)	76.7% (46/60)
1	22% (13/60)	23% (14/60)
≥ 2	3% (2/60)	0

3-month FU
85% of patients were in NYHA class 1 (both groups)

Key safety findings

Mortality
None reported perioperatively or at 3 months' FU

Perioperative complications

	Port-Access endoclamp	Trans-thoracic clamp
New-onset atrial fibrillation	18% (11/60)	15% (9/60)
Re-exploration for bleeding	10% (6/60)	2% (1/60)
Impaired wound healing	7% (4/60)	0
Lymphatic fistula (groin)	3% (2/60)	0
Femoral artery injury	3% (2/60)	0
Ventricle perforation	2% (1/60)	0
Tracheal injury	0	2% (1/60)
Paravalvular leak (minor)	2% (1/60)	0

There was a significant difference in the total number of complications between the 2 groups (p = 0.001)

There were no major complications including cerebrovascular accident or aortic dissection.

Comments

Validity and generalisability of the studies

- Studies were considered relevant for inclusion in either Table 2 or Appendix A if they mentioned specifically that some method of thoracoscopic or robotic assistance was used. Studies that used a minimally invasive incision but did not specify the use of thoracoscopic or computer assistance were excluded.
- There is heterogeneity in the degree and type of thoracoscopic assistance between the studies (the degree of thoracoscopic visualisation used and the combination of direct and thoracoscopic visualisation.
- There is also heterogeneity both between and within studies in relation to technique used for aortic occlusion (endoaortic balloon or transthoracic clamp).

Specialist advisers' opinions

Specialist advice was sought from consultants who have been nominated or ratified by their Specialist Society or Royal College.

Mr Ben Bridgewater, Mr Olaf Wendler, Mr David Richens, Mr Russell Milner, Professor Sir Bruce Keogh, Professor John Dark, Mr Francis Wells

- Five Specialist Advisers stated that this technique, (specifically the videoscopic approach), is a novel procedure and of uncertain safety and efficacy.
- One Specialist Adviser stated that it was a minor variation of an existing procedure (thoracotomy) and considered there to be no uncertainties about the safety or efficacy of the procedure.
- Another Specialist Adviser thought that it had several variations, some of which could be considered extensions of a current technique. This Specialist Adviser stated that some units use a hybrid technique which combines aspects of the Port-Access approach, such as small thoracotomy for access with direct aortic clamping through the trans-thoracic route rather than endovascular balloon clamping.
- One Specialist Adviser was particularly concerned that the quality of valve repair could be compromised in comparison with what can be achieved via conventional sternotomy. He also had concerns about myocardial preservation using an endovascular balloon technique. This Specialist Adviser reported two anecdotal occasions of problems with peripheral cannulation.
- Another Specialist Adviser listed anecdotal cases of aortic dissection (last decade) with the Endoclamp balloon and thought these were related to case selection and product application which has been resolved.
- Another Specialist Adviser stated that there were concerns about the rate of adverse events compared with the conventional approach.
- Two Specialist Advisers thought that there is likely to be significant publishing bias in the literature as the majority of publications come from a few centres with great enthusiasm for and experience in this procedure.

- All Specialist Advisers thought that this was a difficult procedure with a significant learning curve. Some suggested it should only be carried out in specialist cardiac surgical centres with audit and governance structures in place. One Specialist Adviser suggested that the procedure requires input from a multidisciplinary team including nursing staff and perfusionists.
- All of the Specialist Advisers felt that the potential impact on the NHS was minor and that only a minority of hospitals in the UK would carry out the procedure.
- Two Specialist Advisers thought that cost was an important factor, as significant capital is required for the purchase of specialised instruments and robotic apparatus.

Issues for consideration by IPAC

- There is uncertainty over whether this procedure has better outcomes than the conventional sternotomy approach, and there is no randomised controlled trial evidence comparing the two techniques.
- Some authors reported shorter operating times (including CPB and aortic occlusion times) with increased experience and suggested that learning curve phenomena are likely to affect outcomes.
- Some authors have highlighted concerns about femoral arterial cannulation in general (i.e. wound infection, groin haematoma, aortic dissection, atheroemobolism).
- It has been suggested that the endoaortic balloon clamp has a higher risk of aortic dissection. Some authors have stated that they preferred or switched to transthoracic clamp from endoaortic balloon occlusion (Endoclamp) because of better safety and economy. The first report of the Port-Access International Registry showed aortic dissection incidence of 1.30% in the first half of study, which reduced to 0.18% in the second half with improved catheters and guidewires.
- Risk/benefit ratio considerations for this procedure may make it more suitable as a ‘redo’ procedure where repeat sternotomy cannot be performed or is judged to be risky.
- Ten relevant case series were identified but were not included in Appendix A because they were case reports of only 1 or 2 patients.

References

1 **Onnasch JF, Schneider F, Falk V et al. (2002) Five years of less invasive mitral valve surgery: from experimental to routine approach. *Heart Surgery Forum* 5: 132-135.**

2 **Reichenspurner H, Detter C, Deuse T et al. (2005) Video and robotic-assisted minimally invasive mitral valve surgery: a comparison of the Port-Access and transthoracic clamp techniques. *Annals of Thoracic Surgery* 79: 485-490.**

3 **Casselman FP, Van Slycke S, Wellens F et al. (2003) Mitral valve surgery can now routinely be performed endoscopically. *Circulation* Vol. 108: 09-**

4 **Glower DD, Siegel LC, Frischmeyer KJ et al. (2000) Predictors of outcome in a multicenter port-access valve registry. *Annals of Thoracic Surgery* 70: 1054-1059.**

5 **Murphy DA, Miller JS, Langford DA et al. (2006) Endoscopic robotic mitral valve surgery. *Journal of Thoracic & Cardiovascular Surgery* Vol. 132: 781.**

6 **Mishra YK, Khanna SN, Wasir H et al. (2005) Port-access approach for cardiac surgical procedures: our experience in 776 patients. *Indian Heart Journal* 57: 688-693.**

7 **Chitwood WR, Jr. (2005) Current status of endoscopic and robotic mitral valve surgery. *Annals of Thoracic Surgery* 79: S2248-S2253.**

Appendix A: Additional papers on thoracoscopically-assisted, minimally invasive mitral valve surgery not included in summary Table 2

The following table outlines studies that are considered potentially relevant to the overview but were not included in the main data extraction table (Table 2). It is by no means an exhaustive list of potentially relevant studies.

Article title	Number of patients/ follow-up (FU)	Direction of conclusions	Reasons for non-inclusion in Table 2
Autschbach R, Onnasch JF, Falk V et al. (2000) The Leipzig experience with robotic valve surgery. *Journal of Cardiac Surgery* Vol. 15: 87.	n = 167 FU: 1 month Technique: Port-Access	Hospital mortality: 1.2% Conversion to sternotomy: 1/167 Reexploration for bleeding: 4/167 Transient hemiparesis: 3/167 No or trivial regurgitation: 92.6%	More recent study from same centre included in Table 2
Aybek T, Dogan S, Wimmer-Greinecker G et al. (2000) The micro-mitral operation comparing the Port-Access technique and the transthoracic clamp technique. *Journal of Cardiac Surgery* Vol. 15:76-81.	n = 58 FU: Not reported in abstract Technique: Port Access (n = 23), minithoracotomy with transthoracic clamp (n = 35)	No differences between groups in hospital stay, hospital mortality. Operating time, CPB time and blood loss was significantly lower in patients who had trans-thoracic clamp than those who had Port-Access technique.	Larger studies included in Table 2
Casselman FP, Van Slycke S, Dom H et al. (2003) Endoscopic mitral valve repair: feasible, reproducible, and durable. *Journal of Thoracic & Cardiovascular Surgery* 125: 273-282.	n = 187 Mean FU: 19 months Technique: totally endoscopic, endoaortic balloon	Mortality: 1/187 Conversion to sternotomy: 2/187 Median postoperative regurgitation: 0	More recent study from same centre included in Table 2
Casselman FP, Van Slycke S, Wellens F et al. (2003) From classical sternotomy to truly endoscopic mitral valve surgery: A step by step procedure. *Heart, Lung & Circulation* Vol. 12: 177.	n = 190 Mean FU: not stated Technique: endoscopic, endoaortic balloon	Mortality: 2/190 Conversion to sternotomy: 5/190	More recent study from same centre included in Table 2
Chitwood WR, Jr., Wixon CL, Elbeery JR et al. (1997) Video-assisted minimally invasive mitral valve surgery. Journal of Thoracic & Cardiovascular Surgery 114: 773-780.	n = 31 Mean FU: 24 weeks Technique: video-assisted, minithoracotomy, transthoracic clamp	30-day mortality: 3.2% (1/31) Complications: deep venous thrombosis (1), phrenic nerve palsy (1), transient neuropathy (1) NYHA class I or II at f/up: 93%	More recent study from same centre included in Table 2
Chitwood WR, Jr. and Nifong LW. (2000) Minimally invasive videoscopic mitral valve surgery: the current role of surgical robotics. Journal of Cardiac Surgery 15: 61-75.	n = 110 Technique: video-assisted, minithoracotomy, transthoracic clamp	This study reviews several other studies included in either Table 2 or Appendix A	
Cook RC, Nifong LW, Lashley GG et al. (2006) Echocardiographic measurements alone do not provide accurate non-invasive selection of annuloplasty band size for robotic mitral valve repair.[see comment]. Journal of Heart Valve Disease 15: 524-527.	n = 11 FU: not reported Technique: robotically-assisted, minithoracotomy, transthoracic clamp	This studies assesses the feasibility of selecting the annuloplasty band using transoesophageal echocardiograpy alone	Larger or more recent studies included in Table 2
Falk V, Autschbach R, Krakor R et al. (1999) Computer-	n = 10 FU: 3 months (n=7)	Mortality: 0 Conversion to sternotomy: 1/11	Larger or more recent studies

enhanced mitral valve surgery: toward a total endoscopic procedure. Seminars in Thoracic & Cardiovascular Surgery 11: 244-249.	Technique: Port-Access	Minor or no residual regurgitation: 9/11	included in Table 2
Farhat F, Metton O, Aubert S et al. (2006) Results of video-assisted mitral surgery in a non-selected population. Archives des Maladies du Coeur et des Vaisseaux Vol. 99: 127.	n = 72 FU: not reported Technique: video-assisted, minithroacotomy, endoaortic balloon (n= 44), or transthoracic clamp (n= 28)	Mortality: 4 early deaths, 4 late deaths at follow-up (1.8 years). Residual regurgitation grade 1 or 2 (1.8 years): 5/72	Larger or more recent studies included in Table 2
Folliguet T, Vanhuyse F, Constantino X et al. (2006) Mitral valve repair robotic versus sternotomy. European Journal of Cardio-Thoracic Surgery 29: 362-366.	n = 25 (plus 25 matched sternotomy controls) FU: 24 months Technique: minithoracotomy, robotically-assisted, transthoracic clamp	Mortality: 0 Conversion to extended thoracotomy: 1/25 Residual regurgitation: 2 in each group Longer CPB and aortic cross-clamp times, shorter hospital stay in minimally invasive group	Larger or more recent studies included in Table 2
Galloway AC, Shemin RJ, Glower DD et al. (1999) First report of the Port Access International Registry. Annals of Thoracic Surgery 67: 51-56.	n = 321 FU: not reported Technique: Port-Access	Mortality: 8/321 (2.5%) Conversion to sternotomy: 2/321 (7%) New-onset atrial fibrillation: 7% Reoperation: 3% Stroke: 2%	More recent study from same centre included in Table 2
Gersak B, Sostaric M, Kalisnik JM et al. (2005) The preferable use of port access surgical technique for right and left atrial procedures. Heart Surgery Forum 8: E354-E363.	n = 105 (plus 110 sternotomy controls) FU: not reported Technique: Port-Access	Significant differences in favour of Port-Access for: ICU stay, hospital stay, blood transfusion, postoperative thoracic bleeding, and average total patient cost.	Larger or more recent studies included in Table 2
Glower DD, Clements FM, Debruijn NP et al. (1999) Comparison of direct aortic and femoral cannulation for port-access cardiac operations. Annals of Thoracic Surgery 68: 1529-1531.	n = 126 (plus 39 CABG operations) FU: not reported Technique: Port-Access, direct aortic cannulation compared with femoral arterial cannulation	Results not reported separately for mitral valve surgeries and coronary artery bypass graftings.	Larger or more recent studies included in Table 2
Gulielmos V, Wunderlich J, Dangel M et al. (1998) Minimally invasive mitral valve surgery--clinical experiences with a PortAccess system. *European Journal of Cardio-Thoracic Surgery* 14 Suppl 1: S148-S153.	n = 21 FU = 3 months Technique: Port-Access	Mortality: 0 Conversion to sternotomy: 2/21 NYHA class I: 58% NYHA class II: 42%	More recent study from same centre included in Table 2
Gulielmos V, Dangel M, Solowjowa N et al. (1998) Clinical experiences with minimally invasive mitral valve surgery using a simplified Port Access technique. *European Journal of Cardio-Thoracic Surgery* 14: 141-147.	n = 31 FU = 3 months Technique: Port-Access	Mortality: 0 Conversion to sternotomy: 2/31 NYHA class I: 58% NYHA class II: 42%	More recent study from same centre included in Table 2
Gulielmos V, Wagner FM, Waetzig B et al. (1999) Clinical experience with minimally invasive coronary artery and mitral valve surgery with the advantage of cardiopulmonary bypass and cardioplegic arrest using the Port Access technique. *World Journal of Surgery* 23: 480-485.	n = 26 FU = 3 months Technique: Port-Access	Mortality: 0 Conversion to sternotomy: 2/26 NYHA class I: 58% NYHA class II: 42%	More recent study from same centre included in Table 2
Jones BA, Krueger S, Howell D	n = 32	Mortality: 2/32	Larger or more

et al. (2005) Robotic mitral valve repair: A community hospital experience. Texas Heart Institute Journal Vol. 32: 146.	FU: not reported Technique: Robotically-assisted, transthoracic clamp	Conversion to sternotomy: 3/32 Stroke: 1/32 Reoperation for residual regurgitation: 3/32	recent studies included in Table 2
McClure RS, Kiaii B, Novick RJ et al. (2006) Computer-enhanced telemanipulation in mitral valve repair: preliminary experience in Canada with the da Vinci robotic system. Canadian Journal of Surgery 49: 193-196.	n = 10 FU: not reported Technique: Robotically-assisted, transthoracic clamp,	Mortality: 0/10 Conversion to sternotomy: 0/10 Stroke: 0/10 No residual regurgitation: 8/10 Mild residual regurgitation: 2/10	Larger or more recent studies included in Table 2
McCreath BJ, Swaminathan M, Booth JV et al. (2003) Mitral valve surgery and acute renal injury: port access versus median sternotomy. Annals of Thoracic Surgery 75: 812-819.	n = 227 (plus 90 sternotomy controls) FU: not reported Technique: Port-Access	This studies assesses the risk of acute renal injury associated with Port-Access mitral valve surgery vs sternotomy: - reduced acute renal injury in Port-Access patients	Studies with both efficacy and safety outcomes were included in Table 2
Mishra Y, Sharma M, Bapna R et al. (2002) Minimally invasive mitral valve surgery. Indian Heart Journal 54: 279-283.	n = 120 (plus 101 minimally invasive operations using direct vision) Mean FU: 16.4 months Technique: Video-assisted, minithoracotomy, endoaortic balloon clamp and transthoracic clamp	*Results are reported for both video-assisted and direct vision procedures combined* Hospital mortality: 1/221 Groin wound lymphorrhea: 4/221 Chest wound complications: 3/221 NYHA class improved from 2.6 to 1.4	More recent study from same centre included in Table 2
Mohr FW, Falk V, Diegeler A et al. (1998) Minimally invasive port-access mitral valve surgery.[see comment]. Journal of Thoracic & Cardiovascular Surgery 115: 567-574.	n = 17 (plus 131 CABG procedures) FU: 1 to 6 months Technique: Robotically-assisted, Port-Access	All patients alive with normal valve function and free form recurrent mitral insufficiency	More recent study from same centre included in Table 2
Mohr FW, Falk V, Diegeler A et al. (2001) Computer-enhanced 'robotic' cardiac surgery: Experience in 148 patients. Journal of Thoracic & Cardiovascular Surgery Vol. 121: 01-	n = 51 Mean FU: 261 days Technique: Port-Access	Hospital mortality: 5/51 (10%) Conversion to sternotomy or large thoracotomy: 6/51 Dissection: 2/51 Reoperation for paravalvular leakage: 3/52	More recent study from same centre included in Table 2
Mohr FW, Onnasch JF, Falk V et al. (1999) The evolution of minimally invasive valve surgery--2 year experience. *European Journal of Cardio-Thoracic Surgery* 15: 233-238.	n = 129 FU: 804 days (mean) Technique: Endoaortic balloon occlusion or transthoracic clamp	Mortality: 8% in 1st 62 patients, 3% in last 67 Regurgitation: none or trivial in 123/129 patients	More recent study from same centre included in Table 2
Nifong LW, Chu VF, Bailey BM et al. (2003) Robotic mitral valve repair: experience with the da Vinci system. Annals of Thoracic Surgery 75: 438-442.	n = 38 Mean FU: 11 months Technique: Robotically-assisted, minithoracotomy, transthoracic clamp	Mortality: 0 Stroke: 0 Conversion to sternotomy: 0 Reexploration for bleeding: 1/38 Residual regurgitation: grade 0 (12), grade 1 (22), grade 2 (4)	More recent study from same centre included in Table 2
Nifong LW, Chitwood WR, Pappas PS et al. (2005) Robotic mitral valve surgery: a United States multicenter trial. Journal of Thoracic & Cardiovascular Surgery 129: 1395-1404.	n = 112 FU: not reported Technique: Robotically-assisted, minithoracotomy, transthoracic clamp	Mortality: 0 Stroke: 0 Residual regurgitation: - grade 0 or 1: 103/112 - grade 2: 9/112	Larger or more recent studies included in Table 2
Onnasch JF, Schneider F, Falk V et al. (2002) Minimally invasive approach for redo mitral valve surgery: a true benefit for the patient. Journal	n =39 FU: 3 month (n = 25) Technique: Redo mitral valve surgery, Port-Access	Mortality : 2/39 Transient hemiplegia : 1/39 Atrial fibrillation: 9/39 Lung/ pleural adhesions : 8/39 Normal valve function in all	Larger or more recent studies included in Table 2

of Cardiac Surgery 17: 14-19.		patients followed up at 3 months	
Reichenspurner H, Boehm DH, Gulbins H et al. (2000) Three-dimensional video and robot-assisted port-access mitral valve operation. Annals of Thoracic Surgery 69: 1176-1181.	n = 50 FU: 1.5 years Technique: Port-Access	Mortality: 0 Reoperation: 1/50 Paravalvular leak: 1/24 New atrial fibrillation: 4/50 Residual regurgitation: - grade 1: 3/26 - ≥ grade 2: 1/26	Larger or more recent studies included in Table 2
Schroeyers P, Wellens F, De Geest R et al. (2001) Minimally invasive video-assisted mitral valve repair: Short and mild-term results. *Journal of Heart Valve Disease* Vol. 10: 583.	n = 121 Mean FU: 31 months Technique: Port-Access	Mortality: 1/121 Conversion to sternotomy: 2/121 NYHA class: All improved at F/U	More recent study from same centre included in Table 2
Schroeyers P, Wellens F, De Geest R et al. (2001) Minimally invasive video-assisted mitral valve surgery: our lessons after a 4-year experience. *Annals of Thoracic Surgery* 72: S1050-S1054.	n = 175 FU: not reported Technique: Port-Access	Mortality: 2/175 Conversion to sternotomy: 4/175 NYHA class: All improved at F/U	More recent study from same centre included in Table 2
Tatooles AJ, Pappas PS, Gordon PJ et al. (2004) Minimally invasive mitral valve repair using the da Vinci robotic system. Annals of Thoracic Surgery 77: 1978-1982.	n = 25 Mean FU: not reported in abstract Technique: robotically-assisted, transthoracic clamp	Hospital mortality: 0 Conversion to sternotomy: 0 Stroke: 0 Reoperation for bleeding: 0 New atrial fibrillation: 5/25 Reoperation for recurrent insufficiency: 2.25	Larger or more recent studies included in Table 2
Torracca L, Lapenna E, De Bonis M et al. (2006) Minimally invasive mitral valve repair as a routine approach in selected patients. Journal of Cardiovascular Medicine 7: 57-60.	n = 104 Mean FU: 27.4 months Technique: video-assisted, minithoracotomy, endoaortic balloon clamp & transthoracic clamp	Hospital mortality: 0 Conversion to sternotomy: 0 No major complications All but 2 patients in NYHA class 1 at f/up	Larger or more recent studies included in Table 2
Tsai FC, Lin PJ, Chang CH et al. (1996) Video-assisted cardiac surgery. Preliminary experience in reoperative mitral valve surgery.[see comment]. Chest 110: 1603-1607.	n = 4 Mean FU: 2.3 months Technique: video-assisted, redo mitral valve repair or replacement, minithoracotomy	Mortality: 1 death 2 months post-operatively due to sepsis Good prosthesis function in 3 valve replacement patients Mild residual regurgitation in 1 patient	Larger or more recent studies included in Table 2
Vanermen H, Farhat F, Wellens F et al. (2000) Minimally invasive video-assisted mitral valve surgery: From port-access towards a totally endoscopic procedure. *Journal of Cardiac Surgery* Vol. 15: 60.	n = 121 FU: not stated Technique: Port-Access	Mortality: 3/121 Conversion to sternotomy: 5/121 Residual regurgitation: None seen in all except 2 patients	More recent study from same centre included in Table 2
Vanermen H, Wellens F, De Geest R et al. (1999) Video-assisted Port-Access mitral valve surgery: from debut to routine surgery. Will Trocar-Port-Access cardiac surgery ultimately lead to robotic cardiac surgery? Seminars in Thoracic & Cardiovascular Surgery 11: 223-234.	n = 75 FU: not reported Technique: Port-Access	Mortality: 2/75 Conversion to sternotomy: 2/75 Reoperation for bleeding: 5/75	More recent study from same centre included in Table 2

Appendix B: Literature search for thoracoscopically-assisted, minimally invasive mitral valve surgery

IP: 402 Thoracoscopically – assisted minimally invasive mitral valve surgery		
Database	**Date searched**	**Version searched**
Cochrane Library	26/04/2007	2007, Issue 1
CRD databases (DARE & HTA)	26/04/2007	2007, Issue 1
Embase	26/04/2007	1980 to 2007 Week 17
Medline	10/05/2007	1950 to May Week 1 2007
Premedline	26/04/2007	April 24, 2007
CINAHL	26/04/2007	1982 to April Week 3 2007
British Library Inside Conferences	26/04/2007	-
NRR	30/04/2007	2007, Issue 2
Controlled Trials Registry	26/04/2007	-

The following search strategy was used to identify papers in Medline. A similar strategy was used to identify papers in other databases.

1 Thoracoscopy/
2 Thoracoscop$.tw.
3 Video-Assisted Surgery/
4 Surgery, Computer-Assisted/
5 Surgical Procedures, Minimally Invasive/
6 (endoscop$ adj3 pleur$).tw.
7 Thoracotomy/
8 Thoracotom$.tw.
9 minithoracoto$.tw.
10 (port$ adj3 access$).tw.
11 port-access$.tw.
12 or/1-11 (30389)
13 Mitral Valve Insufficiency/
14 Mitral Valve Stenosis/

15 Mitral Valve Prolapse/
16 Mitral Valve/su
17 mitral valve.tw.
18 (Barlow$ adj3 syndrom$).tw.
19 or/13-18
20 12 and 19
21 Animals/
22 Humans/
23 21 not (21 and 22)
24 20 not 23
25 limit 24 to english language
26 limit 25 to yr="1996 - 2007"
27 from 26 keep 1-373