NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedure overview of endoanchoring systems in endovascular aortic aneurysm repair

An aortic aneurysm is a bulge in the wall of the main blood vessel (aorta) carrying blood from the heart to the body. If it bursts, it can cause severe bleeding and death. An aortic aneurysm can be treated by inserting a mesh tube (stent) inside the bulge through cuts in the groin (endovascular) using X-rays to guide it into place. The stent can sometimes leak or move out of place. In this procedure, an anchoring device (endoanchor) is inserted to help hold the stent in place. They may be done at the same time as the stent graft is put in place or during a later procedure if the stent has leaked or moved. The aim is to keep the stent in place and prevent leaks.

Contents

Abbreviations

Word or phrase	Abbreviation
Confidence interval	CI
Endovascular aortic aneurysm repair	EVAR
Manufacturer and User Facility Device Experience	MAUDE
Standard deviation	SD
Thoracic endovascular aortic aneurysm repair	TEVAR

Introduction

The National Institute for Health and Care Excellence (NICE) prepared this interventional procedure overview to help members of the interventional procedures advisory committee (IPAC) make recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the medical literature and professional opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This overview was prepared in September 2021 and updated in March 2022.

Procedure name

- Endoanchoring systems in endovascular aortic aneurysm repair

Professional societies

- British Society of Interventional Radiology
- Vascular Society of Great Britain and Ireland
- Royal College of Radiologists.

Description of the procedure

Indications and current treatment

Aortic aneurysms develop when the wall of the aorta weakens, causing it to bulge and form a balloon-like expansion. They can happen in the chest (thoracic aortic aneurysms) or, more commonly, below the diaphragm (abdominal aortic aneurysms).

The standard treatment for aortic aneurysm is either open surgical or endovascular repair. During open surgical repair the aneurysm is opened and a graft is sewn in above and below the weakened area to allow normal blood flow. Endovascular repair is a minimally invasive alternative to open repair. A graft is mounted on a stent, which is inserted into the aorta through catheters placed in the femoral arteries. The stent–graft is deployed under X-ray guidance and positioned across the aneurysm.

In EVAR procedures, the stent–graft can sometimes leak (endoleak) or move out of place (migrate), or a person's anatomy can make its placement difficult. Type 1 endoleaks happen around the top or bottom of grafts and are often caused by an inadequate seal. Type 1 endoleaks are subdivided into 3 further categories: 1a – proximal, 1b – distal and 1c – iliac occluder.

What the procedure involves

Endoanchoring systems aim to improve the fixation of the stent–graft used in EVAR. They may be used prophylactically or therapeutically at the same time as the primary procedure or during a later, secondary procedure to treat an endoleak or migration.

Endovascular aortic aneurysm repair can be done under general, regional or local anaesthesia. A catheter is inserted through a small incision in the femoral artery and directed to the aortic aneurysm. Contrast is injected into the catheter and X-rays are used to monitor the procedure. A stent–graft is passed through the catheter, advanced to the aneurysm and then opened, creating new walls in the blood vessel. When the stent–graft is deployed it seals the aneurysm. Anchoring implants can then be deployed through an applier device that consists of a catheter and a control handle. The catheter is advanced until the distal end contacts the stent–graft and vessel wall. The number of implants needed depends on the type of stent–graft and size of the native vessel. They are placed as evenly as possible around the circumference of the stent–graft. The catheter is then removed, the holes in the femoral arteries are sutured and the groin wounds closed.

Efficacy summary

Endoanchoring system used during primary procedure

Technical success

In a systematic review of 628 patients, 455 patients had an endoanchoring system used during the primary EVAR procedure (84% for prophylaxis, 15% for intraoperative endoleak and 1% for graft maldeployment). The weighted mean technical success was 98% (95% CI 96% to 100%; Qamhawi 2020).

In a systematic review of 968 patients who had endoanchors placed during an initial EVAR, technical success was 97% (95% CI 93% to 100%; I^2=67%, p=0.01; Karaolanis 2020).

In a cohort study of 319 patients, technical success was 96% in the 242 patients who had an endoanchoring system used during the primary EVAR procedure (Jordan, 2014). In a cohort study of 221 patients, including 175 who had an endoanchoring system used during the primary EVAR procedure, initial technical success was 89% (197/221), and 30-day and follow-up technical success was 96% (211/221; Valdivia 2021).

In a single-arm study of 155 patients, successful device delivery was reported in 99% (153/155) of patients. One patient had conversion to open surgical repair before the endoanchors were placed and the second patient had a different endovascular device placed (Mehta 2014).

In a case series of 86 patients who had therapeutic use of endoanchors, including 25 (29%) who had a revision procedure, a total of 580 endoanchor implants were used. Of these, 170 (29%) were maldeployed (Goudeketting 2019).

Type 1a endoleak

In the systematic review of 628 patients, the weighted mean proportion of patients with a type 1a endoleak after primary fixation during EVAR was 4% (95% CI 2% to 6%) with a mean follow up of 15.4 months (Qamhawi 2020).

In the systematic review of 968 patients, the incidence of type 1a endoleak was 6% (95% CI 1% to 15%; I^2=90%, p=0.00) during a mean follow up of 6 months (Karaolanis 2020).

In the cohort study of 319 patients (242 primary and 77 revision procedures), 29 (9%) patients had a residual type 1a endoleak at the end of the

procedure (Jordan 2014). In the cohort of 221 patients, 5 (2%) had new type 1a endoleaks, 1 had reappearance of a spontaneously sealed type 1a endoleak and 4 patients (2%) had new type 1b endoleaks at 24 months (Valdivia 2021).

In the single-arm study of 155 patients, 1 patient had a type 1 endoleak in the first year of follow up. The primary effectiveness end point (composite of delivery success and absence of type 1 or type 3 endoleaks needing intervention after the index procedure, migration, open surgical conversion, or aneurysm rupture within 1 year of the index procedure) was met in 97% (151/155) of patients (Mehta 2014).

Graft migration

In the systematic review of 628 patients, the weighted mean proportion of patients with graft migration after primary fixation during EVAR was 2% (95% CI 0.1% to 6%) with a mean follow up of 15.4 months (Qamhawi 2020).

In the systematic review of 968 patients, the rate of graft migration was 0.3% (95% CI 0.0% to 2%; I^2=0%) with a mean follow up of 10 months (Karaolanis 2020).

In the single-arm study of 155 patients, endograft migration was reported in 3% (5/155) of patients (Mehta 2014).

Change in aneurysm size

In the systematic review of 968 patients, enlargement of the aneurysmal sac was reported in 2% of patients (95% CI 1% to 3%, I^2=0%). Regression of the aneurysmal sac was reported in 69% of patients (95% CI 51% to 84%, I^2=95%; Karaolanis 2020).

In the non-randomised comparative study, freedom from aneurysm enlargement at 1 year was 97% in the endoanchor group and 96% in the control group (p=0.89). At 2 years it was 97% in the endoanchor group and 94% in the control group (p=0.67). The cumulative incidence of aneurysm sac regression at 1 year was 54% in the endoanchor group and 32% in the control group (p=0.03). At 2 years it was 81% in the endoanchor group and 49% in the control group (p=0.01; Muhs 2018).

In the cohort study of 221 patients, 180 patients had at least 6 months of imaging follow up. Of these, 41% showed sac regression, 51% remained stable and sac enlargement was reported in 8% of patients (Valdivia 2021).

In the single-arm study of 155 patients, aneurysm sac diameter had decreased by more than 5 cm in 44% (62/140) of patients at 6 months, 60% (79/131) at

1 year, 73% (78/107) at 2 years and 82% (67/82) at 3 years. The diameter increased by more than 5 cm in 1% (1/140) of patients at 6 months, 2% (2/131) at 1 year, 3% (3/107) at 2 years and 4% (3/82) at 3 years (Mehta 2014).

Reintervention

In the systematic review of 628 patients, there were 136 aneurysm-related interventions in the 455 patients who had primary fixation; 90% (122) of these were in 74 patients in a single study and were attributed to manufacturing discrepancies in the early design of a specific endograft. There were 3 reinterventions for endoanchor failure (Qamhawi 2020).

In the systematic review of 968 patients, freedom from aneurysm-related reintervention was 98% (95% CI 95 to 99%), with a mean follow up of 10 months (Karaolanis 2020).

In the cohort study of 319 patients, 3% (7/242) of patients in the primary treatment group had a secondary intervention during a mean follow up of 9.3 months. Of the 7 secondary interventions, there was 1 repair of a type 1a endoleak and 1 treatment of type 2 endoleak. There were no interventions for migration (Jordan 2014). In the cohort of 221 patients, freedom from neck-related reinterventions was 98% and freedom from any reintervention was 87% at 24 months (Valdivia 2021).

In the single-arm study of 155 patients, 48% (74/221) of patients had a total of 122 secondary interventions, 92 of which were in patients with thrombus-related events (Mehta 2014).

Survival

In the systematic review of 968 patients, overall survival was 93% (95% CI 90% to 96%; Karaolanis 2020).

In the cohort of 221 patients, overall survival was 89% and freedom from aneurysm-related mortality was 98% at 24 months (Valdivia 2021).

In the single-arm study of 155 patients, overall survival at 1, 2 and 3 years was 97%, 96% and 92% respectively. Freedom from aneurysm-related mortality was 99% (Mehta 2014).

Endoanchoring system used during secondary procedure

Technical success

In a systematic review of 628 patients, 107 patients had an endoanchoring system used during a secondary procedure (56% for type 1a endoleak alone, 11% for graft migration and 33% for type 1 endoleak, graft migration, or both). The weighted mean technical success was 92% (95% CI 86% to 96%; Qamhawi 2020).

In the cohort study of 319 patients, technical success was 91% in the 77 patients who had an endoanchoring system used during a revision procedure (Jordan 2014).

Type 1a endoleak

In the systematic review of 628 patients, the weighted mean proportion of patients with a type 1a endoleak after secondary fixation was 23% (95% CI 9% to 40%) with a mean follow up of 10.7 months (Qamhawi 2020).

In a non-randomised comparative study of 198 patients who had EVAR with or without an endoanchoring system, freedom from type 1a endoleak at 1 and 2 years was 97% for the endoanchor group and 94% for the control group (p=0.34; Muhs 2018).

In the cohort study of 319 patients, 87% of patients in the revision treatment group were free from type 1a endoleak at completion of angiography (Jordan 2014).

Graft migration

In the systematic review of 628 patients, there were no reports of graft migration after secondary fixation, with a mean follow up of 10.7 months (Qamhawi 2020). In the non-randomised comparative study of 198 patients, there was no migration of more than 10 mm in either treatment group within 2 years (Muhs 2018).

Reintervention

In the systematic review of 628 patients, there were 13 aneurysm-related interventions in the 107 patients who had secondary fixation. There were 8 reinterventions for endoanchor failure (Qamhawi 2020).

In the cohort study of 319 patients, there were 11 secondary interventions in 7 patients (9%) in the revision treatment group. These included 7 repairs of a

type 1a endoleak and 4 treatments for type 2 endoleak. There were no secondary interventions for migration (Jordan 2014).

Safety summary

Mortality

All-cause 30-day mortality was 1% (95% CI 0.2% to 2%) in the EVAR cohort of patients (n=562) in the systematic review of 628 patients. For patients who had TEVAR (n=66), weighted all-cause 30-day mortality was 12% (95% CI 5% to 21%; Qamhawi 2020).

There was no aneurysm-related mortality, and mortality not related to the procedure was 5% (6/116) in 116 patients with unfavourable neck characteristics included in the systematic review of 968 patients (Karaolanis 2020).

Mortality was 3% (9/319) in the cohort of 319 patients, none of which was aneurysm or device related (Jordan 2014).

Aneurysm-related mortality within 30 days was 2% (4/221) in a cohort study of 221 patients; 1 patient died from multiorgan failure, 2 died from sepsis and pneumonia and 1 died from an endograft infection. Non-aneurysm-related mortality during follow up was 10% (21/221).

There was 1 death within 30 days in the single-arm study of 155 patients. The patient died 18 days after the index procedure, which had been complicated by the rupture of an iliac artery during balloon angioplasty of a graft limb. There was 1 additional aneurysm-related death after 3 years caused by haemorrhagic stroke. This was adjudicated to be related to warfarin prescribed to treat a pulmonary embolism after an abdominal aortic aneurysm-related reintervention (Mehta 2014).

There were 27 deaths reported during the index hospitalisation or during follow up on the FDA MAUDE database. Of these, 15 were of unknown aetiology or considered to be unrelated to the index procedure, and 12 reports were thought to be related to the index EVAR procedure rather than endoanchor use. In 1 report, multiple tiny holes were seen at the site of endoanchor insertion at the time of explant. The reporting physician thought these contributed to worsening of the endoleak (Masoomi 2019).

Aneurysm rupture

No aneurysm rupture was reported in the systematic review of 968 patients with mean follow up of 10 months (Karaolanis 2020).

Endoanchor fracture, dislocation, or entrapment

Endoanchor fracture and dislocation were each reported in 3 patients who had EVAR in the systematic review of 628 patients. An entrapped endoanchor needing snare retrieval was reported in 1 patient in the same review. A maldeployed endoanchor was reported in 2 patients who had TEVAR. In 1 of these patients, the endoanchor was irretrievable, resulting in a retrograde type A aortic dissection and death (Qamhawi 2020).

Endoanchor fractures were reported in 2% (4/221) of patients (no treatment was necessary) in the cohort study of 221 patients. Endoanchor losses were reported in 2% (4/221) of patients, 2 were snared, 1 was caged and 1 was left in the main endograft body. There were also 2 reports of a twisted device in the same study, which were treated by changing the catheter. None of these issues caused any type of intraoperative or follow-up complication or failure (Valdivia 2021).

Endoanchor dislodgement or fracture was described in 65 reports in the FDA MAUDE database (1% of estimated total device systems used). Guide or applier malfunction was described in 20 reports (Masoomi 2019).

Myocardial infarction

Myocardial infarction was reported in 1% (2/155) of patients within 30 days, 5% (7/155) within 1 year and 7% (10/155) within 3 years of the index procedure in the single-arm study of 155 patients (Mehta 2014).

Stroke

Stroke was reported in 2% (3/155) of patients within 1 year and 5% (7/155) within 3 years of the index procedure in the single-arm study of 155 patients (Mehta 2014).

Renal failure

Renal failure was reported in 1% (2/155) of patients within 1 year and 4% (6/155) within 3 years of the index procedure in the single-arm study of 155 patients (Mehta 2014).

Thrombus-related events

Device-related thrombotic events were reported in 21% (32/155) of patients (49 events) within 1 year of implantation and 36% (56/155) of patients (104 events) within 3 years. Limb occlusion was 5% (7/155) at 1 year and 8% (12/155) at 3 years. Distal embolic events linked to the endograft were reported in 10% (15/155) of patients at 1 year and 15% (23/155) at 3 years. Non-occlusive

thrombus identified by imaging was reported in 10% (15/155) at 1 year and 21% (33/155) at 3 years. The authors noted that the endograft device was subsequently modified to reduce the rate of thrombus-related events (Mehta 2014).

Air embolism

Air embolism associated with the use of endoanchors in EVAR was described in 5 reports in the FDA MAUDE database (0.07% of estimated total device systems used). No long-term clinical consequences were reported (Masoomi 2019).

Air embolisation to the ascending aorta immediately after deployment of endoanchors was described in a case report (Rosu 2021).

Respiratory failure

Respiratory failure was reported in 1% (1/155) within 1 year and 2% (3/155) within 3 years of the index procedure in the single-arm study of 155 patients (Mehta 2014).

Anecdotal and theoretical adverse events

In addition to safety outcomes reported in the literature, professional experts are asked about anecdotal adverse events (events they have heard about) and about theoretical adverse events (events they think might possibly occur, even if they have never happened).

For this procedure, professional experts did not describe any anecdotal adverse events. They considered that the following were theoretical adverse events: endoanchoring close to the renal arteries could cause hypotension during the procedure; there is potential for an endoanchor to be detached from the delivery system and embolise distally; vascular access complications; the delivery of the anchors can be time consuming, with the X-ray gantry at high angles which increases the X-ray dose to the patients and operators; and there is a potential for skin damage in doses greater than 1 gray.

The evidence assessed

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to use of endoanchoring systems in endovascular aortic aneurysm repair. The following databases were searched, covering the period from their start to 12 January 2022: 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 the literature search strategy). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The inclusion criteria were applied to the abstracts identified by the literature search. Where selection criteria could not be determined from the abstracts the full paper was retrieved.

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 a laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising study methodology, unless they reported specific adverse events that were not available in the published literature.
Patient	Patients who have had or are having endovascular aortic aneurysm repair.
Intervention/test	Use of endoanchoring systems.
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 IP overview

This IP overview is based on about 1,500 patients from 2 systematic reviews, 1 non-randomised comparative study, 2 cohort studies, 1 single-arm study (which was also included in the systematic reviews), and 1 case report (Qamhawi 2020; Karaolanis 2020; Muhs 2018; Jordan 2014; Valdivia 2021; Mehta 2014; Rosu 2021). There is also a case series of 229 reports from the FDA MAUDE database (Masoomi 2019). There is some patient overlap between the studies. Most of the evidence described the use of endoanchors during a primary EVAR procedure. In 1 systematic review, 73% (455/628) of procedures were primary EVAR procedures and endoanchors were used prophylactically in 84% (381/455) of

these. The second systematic review only included primary procedures and endoanchors were used prophylactically in 77% (742/968) of these.

Other studies that were considered to be relevant to the procedure but were not included in the main summary of the key evidence are listed in the appendix.

Summary of key evidence on endoanchoring systems in endovascular aortic aneurysm repair

Study 1 Qamhawi Z (2020)

Study details

Study type	Systematic review and meta-analysis
Country	Not reported for individual studies
Recruitment period	Search date: June 2019
Study population and number	n=628 (562 patients had EVAR and 66 had TEVAR) Patients who had EVAR or TEVAR with endoanchor fixation (prophylactic or therapeutic)
Age and sex	• Endoanchor fixation during primary EVAR: weighted mean age 73.8 years, 85% male • Endoanchor fixation during secondary procedure after EVAR: weighted mean age 77.4 years; 74% male • Endoanchor fixation during TEVAR (primary or secondary): weighted mean age 68.5 years; 65% male
Patient selection criteria	Inclusion criteria for studies: original cohort studies of patients who had EVAR or TEVAR with endoanchor fixation and outcome measures included descriptive rates of type 1a endoleak, graft migration, and complications after endoanchor fixation. Data sources were PubMed/ MEDLINE, Embase, and the Cochrane Library. There were no language limitations. Multiple publications corresponding to a single cohort study were considered to be part of a single entity. Scientific abstract articles, studies of 5 or fewer patients, and pre-clinical studies were excluded. A study that used the Anson Refix Endostapler device (Lombard Medical Technologies, UK) was excluded from the review because the device was no longer commercially available.
Technique	Endoanchoring system: Heli-FX EndoAnchor system. Various grafts were used, including Aptus, Gore Excluder, Endurant, Zenith, Incraft, Talent, AneuRx, Cook, Gore, Medtronic. Some patients had adjunctive proximal procedures alongside endoanchors.
Follow up	• Endoanchor fixation during primary EVAR: mean 15.4 months • Endoanchor fixation during secondary procedure after EVAR: mean 10.7 months • Endoanchor fixation during TEVAR (primary or secondary): weighted mean 9.8 months
Conflict of interest/source of funding	None

Analysis

Follow-up issues: The authors noted there was a high attrition rate at follow up.

Study design issues: The systematic review was conducted according to the 2009 Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement. Inclusion criteria were met by 14 single arm, open label studies. The median Newcastle-Ottawa score was 5 (range 5 to 6). There were no case controlled trials. Nine studies were included in the meta-analysis. The use of proximal adjunctive procedures, such as aortic extension cuffs, was not accounted for. For TEVAR, the meta-analysis was combined for primary and secondary procedures as outcomes were not consistently distinguished between the 2 subgroups.

Study population issues: Weighted aortic neck characteristics were generally favourable. In most patients, the endoanchoring system was used prophylactically during a primary EVAR (n=381).

Of the 9 studies included in the meta-analysis, 2 were also included in the systematic review by Karaolanis et al. (2020). Results from the ANCHOR registry were included in both systematic reviews, but from different publications.

Key efficacy findings

Number of patients analysed: 628 (562 EVAR, 66 TEVAR)

Weighted meta-analysis of proportions for rate of Type 1a endoleak and graft migration in patients with EVAR and endoanchor fixation by indication for endoanchor use

Indication for endoanchor	Number of patients, n (%)	Technical success %, weighted mean (95% CI)	Follow up period in months, weighted mean (95% CI)	Patients completed follow up, n (%)	Follow up type 1a endoleak %, weighted mean (95% CI)	Follow up graft migration %, weighted mean (95% CI)
Primary fixation	455	98.4 (95.7 to 99.8)	15.4 (1.8 to 29.0)	288 (63.3)	3.5 (1.7 to 5.9)	2.0 (0.12 to 6.0)
Prophylaxis	381 (83.7)	-	-	233 (59.1)	2.8 (1.1 to 5.3)	2.2 (0.22 to 6.3)
Intraoperative type 1a endoleak	70 (15.4)	-	-	51 (72.8)	8.2 (1.9 to 18.2)	0
Graft maldeployment	4 (0.88)	-	-	4 (100)	0	0
Secondary fixation	107	91.8 (86.1 to 96.2)	10.7 (7.8 to 13.6)	74 (69.2)	22.6 (9.1 to 40.0)	0
Type 1a endoleak alone	60 (56.1)	-	-	44 (73.3)	39.3 (26.0 to 53.5)	0
Graft migration	12 (11.2)	-	-	7 (58.3)	0	0

Type 1 endoleak and/or graft migration	35 (32.7)	-	-	23 (65.7)	6.6 (0.5 to 19.3)	0

EVAR with primary fixation (n=455)

- Aneurysm related reinterventions, n=136 (122 [89.7%] were in 74 patients in a single study)
- Reinterventions for endoanchor failure, n=3

In a reported 196 primary EVAR patients, aneurysm sac diameter decreased by more than 5 mm in 55.3% (95% CI 41.3 to 69.0, I^2=65.1%, p=0.057) of patients. There was no change in 43.5% (95% CI 29.5 to 58.9, I^2=69.1%, p=0.040) of patients, while sac diameter increased by more than 5 mm in 1.4% (95% CI 0.25 to 3.5, I^2=0%, p=0.70) of patients after endoanchor fixation.

EVAR with secondary fixation (n=107)

- Aneurysm related reinterventions, n=13
- Reinterventions for endoanchor failure, n=8

TEVAR (29 primary, 31 secondary, 6 indeterminate)

- Technical success=90.3% (95% CI 72.1 to 99.4, I^2=54.0%, p=0.11)
- Overall rate of type 1a endoleak=8.7% (95% CI 1.0 to 18.9%, I^2= 64.4%, p=0.060) at follow up
- There were no graft migrations.
- Aneurysm related reinterventions, n=9
- Reinterventions for endoanchor failure, n=1

Key safety findings

Adverse events in EVAR cohort

- Endoanchor fracture, n=3
- Dislocated endoanchor, n=3
- Entrapped endoanchor needing snare retrieval, n=1
- Common iliac artery dissection caused by wire manipulation needing a covered stent, n=1
- All cause 30-day mortality=0.82% (95% CI 0.20 to 1.85, I^2=0%, p=0.8)

Adverse events in TEVAR cohort

- Maldeployed endoanchor, n=2; in 1 patient, the endoanchor was irretrievable resulting in a retrograde type A aortic dissection and death.
- Weighted all cause 30-day mortality=11.9% (95% CI 5.4 to 20.6, I^2=0%, p=0.59)
- Deaths not directly attributed to endoanchor use, n=6 (2 respiratory failure, 1 ruptured thoracic aneurysm from undiagnosed endoleak, 1 intracranial haemorrhage, 1 ruptured iliac artery aneurysm, and 1 multiple visceral or cerebral infarctions).

Study 2 Karaolanis G (2020)

Study details

Study type	Systematic review and meta-analysis
Country	Not reported for individual studies
Recruitment period	Search date: July 2019
Study population and number	n=968 (8 articles) Patients who had endoanchors placed during an initial EVAR to prevent or repair intraoperative type 1a endoleak (prophylactic or therapeutic).
Age and sex	Mean 73.4 years; 81.4% (627/770) male (not reported in 1 study of 198 patients)
Patient selection criteria	English language studies reporting on primary use of endoanchors in patients having standard EVAR with or without unfavourable aortic neck were considered eligible. Primary use of endoanchors was defined as the placement of endoanchors during the initial EVAR to prevent or repair intraoperative type 1a endoleak. Only studies with 10 or more patients were included in the meta-analysis, while case reports, series with fewer than 10 patients and reviews of the literature were excluded from the analysis. Studies that referred to implantation of endoanchors but did not report outcome data were excluded. Duplicates were excluded, while in the case of metachronous publications from the same surgical group, only the latest article or the article with the largest number of patients was included.
Technique	Endoanchor device: Aptus Heli-FX EndoAnchor System (Medtronic Vascular, US) Endoanchors were used for prophylaxis in 742 (77%) patients and to treat an intraoperative type 1a endoleak in 127 (13%) patients. The mean number of endoanchors deployed per patient was 4 in 2 studies and 5 in 5 studies, only 1 study used 6 endoanchors.
Follow up	Mean 10 months (mean imaging follow up was 6 months)
Conflict of interest/source of funding	None for the systematic review.

Analysis

Follow-up issues: The authors noted that the limited follow-up period of the eligible studies precluded a long-term assessment of the utility of the endoanchors as a definite prophylactic adjunct.

Study design issues: There were no randomised controlled trials. Of the 8 included studies, 4 were prospective and 4 were retrospective. The meta-analysis was done according to The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The Newcastle–Ottawa tool was used to evaluate the methodologic quality of the studies. The maximum possible score for a study is 9, based on 3 broad perspectives: (1) selection of the study groups, (2) comparability of the groups and (3) ascertainment of outcome of interest. The median score of the 8 included articles was 6 (range 5 to 6). The main early outcome was the technical success and late outcomes included the incidence of type 1a endoleak, migration and the

number of patients who had regression or expansion of the aneurysm sac throughout the follow-up period. Secondary outcome endpoints were the freedom of aneurysm-related reintervention, the rate of aneurysm rupture and the overall survival rate. There were differences in definitions and follow-up imaging between the studies, which contributed to heterogeneity. There was a lack of information about the co-existence of type 2 endoleaks, which may have led to persistence of low flow type 1a endoleaks.

Study population issues: Anatomical neck characteristics of hostile neck were reported only in 2 studies, including 116 patients.

Of the 8 studies, 2 were also included in the systematic review by Qamhawi et al. (2020). Results from the ANCHOR registry were included in both systematic reviews, but from different publications.

Key efficacy findings

Number of patients analysed: 968

- **Technical success** (defined as successful implantation of endoanchors with adequate penetration of the aortic wall and absence of a type 1a endoleak at completion angiography = 97.1% (95% CI 93.0 to 99.7; 6 studies; I^2=66.9%, p=0.01)
- **Incidence of type 1a endoleak after primary use of endoanchors** = 6.2% (95% CI 0.8 to 15.3; 5 studies; I^2=90.3%, p=0.00) These endoleaks were detected on CT angiography during a mean follow-up period of 6 months (range 17 ± 12.14 months).
- **Migration of main graft** (needing an additional proximal aortic cuff because of persistent type 1a endoleak = 0.3% (95% CI 0.0 to 1.5; 5 studies; I^2=0.0%)
- **Regression of the aneurysmal sac** = 68.8% (95% CI 51.0 to 84.2; 6 studies; I^2=95.3%, p=0.00)
- **Expansion of the aneurysmal sac** = 1.9% (95% CI 0.9 to 3.2; 6 studies; I^2=0.0%)
- **Freedom of aneurysm-related reintervention** (mean follow-up 10 months) = 97.7% (95% CI 95.2 to 99.4; 4 studies)
- **Overall survival** (mean follow-up 10 months) = 93.4% (95% CI 90.0 to 96.3; 4 studies)

Results in patients with 'hostile neck' characteristics (n=116, 2 studies)

- Crude rate of type 1a endoleak after primary use of endoanchors = 19.6% (18/92)
- Crude rate of type 2 endoleak during follow up = 18.1% (21/116)
- Proportion of patients needing additional proximal aortic cuff because of graft migration = 0.9% (1/116)
- Reintervention rate = 6.9% (8/116)

Key safety findings

- Misdeployment of the endoanchors at the end of the procedure was observed in a ‘few cases’ because of a heavily calcified aorta. This was resolved using additional staples for better fixation of the endograft. In the short-term follow-up period, no other additional complication related to endoanchors was reported.

- No aneurysm rupture was recorded during follow up (4 studies).

- In the 116 patients with unfavourable neck characteristics, there was no aneurysm-related mortality and mortality not related to the procedure was 5.2% (6/116).

Study 3 Muhs B (2018)

Study details

Study type	Non-randomised comparative study (using data from ANCHOR registry)
Country	US and The Netherlands
Recruitment period	2009 to 2014
Study population and number	n=198 (99 EVAR with prophylactic endoanchoring system, 99 EVAR alone) Patients who had EVAR of abdominal aortic aneurysm
Age and sex	Not reported
Patient selection criteria	Patients with asymptomatic, symptomatic, or ruptured abdominal aortic aneurysms were eligible for study inclusion. Patients who had prophylactic endoanchor treatment were assessed by investigators to be at high risk for later complications, with most meeting at least 1 hostile neck criterion (aortic diameter at the renals >28 mm, proximal neck length <10 mm, infrarenal angulation to bifurcation >60 degrees, neck thrombus thickness ≥2 mm, neck thrombus circumference >180 degrees, neck calcium thickness ≥2 mm, and neck calcium circumference >180 degrees).
Technique	Endoanchoring device: Aptus Heli-FX EndoAnchor System (Medtronic, US) In the endoanchor group, endoanchors were used at the time of the primary EVAR procedure, either to treat perioperative type 1a endoleak or for prophylaxis of neck-related complications. Control group: patients had conventional EVAR without adjunctive use of endoanchors. In both groups, the Medtronic Endurant endograft was the most commonly used device for EVAR. Other devices included Medtronic Talent, Gore Excluder, Cook Zenith, Lombard Aorfix, Endologix AFX or Powerlink and TriVascular Ovation.
Follow up	2 years
Conflict of interest/source of funding	Medtronic sponsored the ANCHOR arm of the study. 1 author disclosed clinical research grants and consulting fees from Medtronic, Gore, Cook, and Endologix. 1 author disclosed consulting fees from Medtronic, Cook, and Endologix and also that he was the former CEO of Aptus. 1 author disclosed that he was employed by and held equity in Syntactx, a company that received research funding from Medtronic (the sponsor of the work). 1 author disclosed clinical research grants from Endologix and consulting fees from Medtronic and Endologix.

Analysis

Study design issues: Retrospective comparison of propensity-matched cohorts, matched based on anatomic criteria. Consent was limited to baseline and follow-up imaging for the control cohort, so there was a lack of clinical outcome data. Standardised differences between baseline anatomical characteristics were calculated using Cohen's effect size classifications for small, medium, large, and very large effect sizes (0.2, 0.5, 0.8, and 1.3, respectively). A standardised difference less than 0.2 was determined to indicate a minimal imbalance between the cohorts.

IP overview: endoanchoring systems in endovascular aortic aneurysm repair

Study population issues: There was a lack of baseline demographic data and procedural data for control patients, so matching was done on anatomic criteria alone.75% of patients in the endoanchor group and 56% of patients in the control group met at least 1 criterion for hostile neck. The most common hostile neck characteristic observed in each cohort was severe aortic neck calcification, seen in 33% of patients in the endoanchor group and 27% of patients in the control group. There were large differences between the cohorts with regard to proximal and visual neck length (control patients had longer proximal and visual necks, on average). A very large difference was calculated for thrombus circumference (mean 37.2° for the endoanchor group compared with 22.9° in the control group). The standardised difference between the overall anatomic profile of the 2 cohorts was calculated as -0.2, the threshold determining a small difference. Cox regression analyses were done to assess whether any variables were predictive for later aneurysm sac regression.

Endograft migration was defined as movement of the graft >10 mm from its first postprocedural CT scan. Aneurysm sac enlargement was defined as an increase in maximum aneurysm diameter >5 mm from the baseline imaging study. Aneurysm regression was defined as a reduction of maximum diameter >5 mm.

Other issues: patients from the ANCHOR registry have been included in several other publications, including the systematic review by Qamhawi et al., 2020.

Key efficacy findings

Number of patients analysed: 198 (99 endoanchor, 99 control)

Endoleaks and migration

- At 1 year, 2 patients in the endoanchor group and 4 patients in the control group had a type 1a endoleak. There were no further type 1a endoleaks reported through 2-year follow-up.

- Freedom from type 1a endoleak at 1 and 2 years (Kaplan-Meier analysis):
    - Endoanchor group=97% ± 2.1%
    - Control group=94.1% ± 2.5%, p=0.34

- At 1 year, 15 patients in the endoanchor group and 17 patients in the control group had a type 2 endoleak. One additional patient in the control group had a type 2 endoleak at 2-year follow-up.

- At 1 year, 4 patients in the endoanchor group and 1 patient in the control group had a type 3 endoleak.

- There was no migration more than 10 mm in either group within 2 years.

Neck dilation and aneurysm enlargement

- Neck dilation 4 mm or more was reported in 3 patients in the endoanchor group and 8 in the control group within 2 years.

- Freedom from neck dilation at 1 year (Kaplan-Meier analysis):
    - Endoanchor group=98.4% ± 1.6%
    - Control group=94.9% ± 2.5%, p=0.27

- Freedom from neck dilation at 2 years (Kaplan-Meier analysis):
  - Endoanchor group=90.4% ± 5.6%
  - Control group=87.3% ± 4.3%, p=0.46

- Aneurysm enlargement more than 5 mm at 2 years was reported in 2 patients in the endoanchor group and 4 in the control group.

- Freedom from aneurysm enlargement at 1 year (Kaplan-Meier analysis):
  - Endoanchor group=97.0% ± 2.1%
  - Control group=96.0% ± 2.3%, p=0.89

- Freedom from aneurysm enlargement at 2 years (Kaplan-Meier analysis):
  - Endoanchor group=97.0% ± 2.1%
  - Control group=94.0% ± 3.0%, p=0.67

Aneurysm sac regression

- At 1 year, 29 patients in the endoanchor group and 25 in the control group had aneurysm sac regression. At 2 years, an additional 6 patients in the endoanchor group and 11 in the control group had sac regression.

- Cox regression analysis found an inverse correlation between number of hostile neck criteria met and later sac regression (p=0.05). With each increase in number of hostile criteria met, patients were 23% less likely to experience later sac regression (p=0.046). No other baseline or procedural variables were found to be statistically significantly associated with later sac regression, apart from treatment received (EVAR with or without endoanchors), which was found to be predictive in all multivariate analyses.

- Cumulative incidence of aneurysm sac regression at 1 year (Kaplan-Meier analysis):
  - Endoanchor group=53.5% ± 7.0%
  - Control group=32.3% ± 5.3%, p=0.03

- Cumulative incidence of aneurysm sac regression at 2 years (Kaplan-Meier analysis):
  - Endoanchor group=81.1% ± 9.5%
  - Control group=48.7% ± 5.9%, p=0.01

Summary statistics of variables predictive for sac regression, mean (SD); range

Predictive variable	Endoanchor group – regression, n=64	Endoanchor group – no regression, n=35	p	Control group – regression, n=63	Control group – no regression, n=36	p
Neck thrombus circumference, degrees	38 (76); 0 to 320	35 (60); 0 to 175	0.85	35 (66); 0 to 300	2 (9); 0 to 54	0.003
Infrarenal neck diameter, mm	25 (4); 17 to 37	25 (4); 20 to 34	0.89	26 (4); 18 to 35	24 (3); 17 to 29	0.004

IP overview: endoanchoring systems in endovascular aortic aneurysm repair

Neck thrombus and sac regression, n (%)

Outcome	Endoanchor group – with thrombus, n=30	Endoanchor group – no thrombus, n=69	p	Control group – with thrombus, n=18	Control group – no thrombus, n=81	p
Sac regression	10 (33)	25 (36)	0.82	1 (6)	35 (43)	0.001
No sac regression	20 (67)	44 (64)		17 (94)	46 (57)	

Infrarenal neck diameter and sac regression, n (%)

Outcome	Endoanchor group – infrarenal diameter >28 mm, n=18	Endoanchor group – infrarenal diameter <28 mm, n=81	p	Control group – infrarenal diameter >28 mm, n=21	Control group – infrarenal diameter <28 mm, n=78	p
Sac regression	8 (44)	27 (33)	0.50	2 (10)	34 (44)	0.004
No sac regression	10 (56)	54 (67)		19 (90)	44 (56)	

Key safety findings

No safety data were reported.

Study 4 Jordan W (2014)

Study details

Study type	Cohort study (ANCHOR registry, NCT01534819)
Country	US, The Netherlands, Germany, Italy, UK (43 sites)
Recruitment period	2012 to 2013
Study population and number	n=319 (242 primary, 77 revision) Patients who had prophylactic or therapeutic endoanchor implantation with EVAR
Age and sex	Mean 74.1 years; 74.6% (238/319) male
Patient selection criteria	Eligible patients included those with asymptomatic, symptomatic, or ruptured abdominal aortic aneurysm, adequate iliofemoral access, life expectancy of 1 year or more and no history of allergy to the metallic components of the device. Exclusion criteria included prior endoanchor implantation, known bleeding diathesis, infection, and significant proximal aortic neck thrombus or calcium that would preclude adequate endoanchor penetration into the aortic wall.
Technique	Device: Heli-FX EndoAnchor System (Aptus Endosystems, US) The primary arm comprised those patients with endoanchor implantation at the same procedure as the initial EVAR procedure. Patients in the primary arm were treated for prophylaxis of endoleak or migration when, in the opinion of the investigator, the anatomy put the patient at risk for future proximal aortic neck complications. Patients were also included in the primary arm when endoanchors were used to treat a type 1a endoleak evident at the time of an initial EVAR procedure. The revision arm included patients who had prior EVAR and presented with type 1a endoleak or endograft migration. Aortic extender cuffs were usually used in this group when the original endograft was not adequately juxtaposed to the lowest renal artery, from either migration or misdeployment. Suitable endografts included the Zenith (Cook, US), the Excluder (WL Gore, US) and the AneuRx, Talent, or Endurant devices (Medtronic Vascular, US). The median number of endoanchors deployed was 5 in the primary arm and 7 in the revision group. Most procedures (89%) were done under general anaesthesia.
Follow up	Mean 9.3 months
Conflict of interest/source of funding	7 authors have received research grants or fees from companies including WL Gore & Associates, Medtronic Inc, Aptus Endosystems Inc, Endologix, Lombard Medical Technologies, Trivascular Inc, Cordis Corporation, Bolton Medical Inc, Abbott Vascular Inc, Terumo Cardiovascular Systems Corp, Cook Medical, MEDRAD Inc, Silroad Medical. 1 author has equity ownership in and is employed by Syntactx, a company that receives fees for contract research activities from Aptus Endosystems Inc.

Analysis

Follow-up issues: Follow-up was done according to each investigator's standard of care.

Study design issues: Single-arm, prospective, multicentre, multinational registry. Consent could be obtained before endoanchor implantation or within 30 days after endoanchor implantation to include those patients with unplanned use of the device. To exclude selection bias, investigators were asked to enrol patients before the first postoperative imaging study. The primary efficacy end point was successful implantation of the minimum number of endoanchors as defined in the Instructions for Use with respect to the diameter of the aortic neck and freedom from endograft migration (>10 mm) or type 1a endoleak at 12 months. The primary safety end point was a composite defined as freedom from serious adverse device-related events or procedure-related adverse events during 12 months, excluding those events solely attributable to the endograft or the endograft implantation procedure but including aneurysm-related mortality. Technical success was defined as deployment of the desired number of endoanchors with adequate penetration of the vessel wall and without endoanchor fracture and with uneventful removal of the Heli-FX Guide. Procedural success was defined as technical success without a type 1a endoleak at completion angiography.

Study population issues: Aneurysms were asymptomatic in 87.8% of patients and symptomatic in 12.2%. Ruptured aneurysms were reported in 1.0% of patients. The American Society of Anesthesiologists physical status was 1 in 3 patients (0.9%), 2 in 29 patients (8.9%), 3 in 228 patients (71.5%), and 4 in 59 patients (18.5%). The mean aneurysm diameter at the time of the procedure was 58 mm. The mean proximal aortic neck was 16 mm in length (42.7% were less than 10 mm and 42.7% were conical) and 27 mm in diameter; infrarenal neck angulation was 24 degrees.

Key efficacy findings

Number of patients analysed: 319 (242 primary, 77 revision)

Technical success

- All patients=95.0%
- Primary group=96.3%
- Revision group=90.9%

Procedural success

- All patients=87.5%
- Primary group=89.7%
- Revision group=80.5%

Freedom from type 1a endoleak at completion angiography

- All patients=90.9%
- Primary group=92.1%
- Revision group=87.0%

Secondary interventions, n (%)

Secondary intervention	Primary group, n=242	Revision group, n=77	All, n=319
Open surgical conversion	0	0	0
Repair of type 1a endoleak	1 (0.4)	7 (9.1)	8 (2.5)
Treatment of type 2 endoleak	1 (0.4)	4 (5.2)	5 (1.6)
Treatment of migration	0	0	0
Treatment of graft limb kinking	1 (0.4)	1 (1.3)	2 (0.6)
Treatment of graft limb occlusion	2 (0.8)	1 (1.3)	3 (0.9)
Treatment of access vessel injury	1 (0.4)	0	1 (0.3)
Lower extremity revascularisation	2 (0.8)	1 (1.3)	3 (0.9)
Total secondary procedures	7 (2.9)	11 (14.3)	18 (5.6)
Total patients with secondary procedures	7 (2.9)	7 (9.1)	14 (4.4)

Note: some procedures addressed more than 1 indication

Of the 18 secondary procedures, 8 (44.4%) were within 30 days of the index procedure, 5 (29.4%) were between 31 and 90 days, and 5 (29.4%) were more than 180 days after the index procedure.

Key safety findings

Primary safety endpoint

- All patients=92.2% (294/319)
- Primary group=93.4% (226/242)
- Revision group=88.3% (68/77)

‘No patient experienced an unanticipated adverse device effect.’

Mortality

- There were 9 deaths during follow-up (2.8%), none of which was aneurysm related or device related.

Study 5 Valdivia A (2021)

Study details

Study type	Cohort study (PERU registry, NCT04100499)
Country	Greece, Italy, The Netherlands, Spain, UK, US (7 centres)
Recruitment period	2010 to 2019
Study population and number	n=221 (175 primary, 46 revision) Patients who had endoanchoring systems used to prevent or repair failure during infrarenal endovascular aneurysm repair
Age and sex	Mean 75.6 years; 83% (184/221) male
Patient selection criteria	The decision to use endoanchors was made by the treating surgeon or multidisciplinary aortic committee according to each centre's practice. All on-label cases were included. Hostile neck conditions, including severely angulated necks were not considered a reason for exclusion. "Hostile neck" was defined as neck length <10 mm and 1 or more of the following criteria: infrarenal angle >60°, thrombus with >2 mm thickness in >50% circumference or circumferential calcification >50%, conical neck (gradual neck dilation >2 mm) along the 10 or 15 mm infrarenal neck length, and diameter >28 mm or asymmetric neck bulge(s). Patients included in the ANCHOR registry were excluded from this analysis.
Technique	Endoanchoring device: Heli-FX EndoAnchor System (Medtronic Vascular, US) The primary group (79.2%) included all patients who had endoanchors as a preventive measure or for an intraoperative type 1a endoleak and the revision group (20.8%) included those patients where endoanchors were used (either alone or with adjunctive endografts) to treat a post-EVAR failure (migration alone, type 1a endoleak, or both). Of the 221 patients, 193 (87.3%) had suprarenal fixation endografts, with the Endurant endograft (Medtronic, US) being the most common (n=112; 50.7%). Other endografts included Incraft (Cordis Corporation, US) and E-Tegra (JOTEC GmbH, Germany). The median number of endoanchors deployed per patient was 6. Adjunctive procedures were used in 10.9% (24/221) of patients.
Follow up	Median 27 months (interquartile range 12 to 48)
Conflict of interest/source of funding	The authors received no financial support for the research, authorship, and publication of this article. Of the 14 authors, 7 are consultants for Medtronic.

Analysis

Follow-up issues: Follow-up imaging was scheduled according to each centre's protocol and included either abdominal ultrasound or radiography or CT scan imaging.

Study design issues: Observational retrospective study of prospectively collected data from 7 vascular surgery departments. The main outcomes were technical success, freedom from type 1a endoleak and sac diameter evolution. Technical success was defined as freedom from type 1 endoleak at the end of the primary

procedure, where endoanchors were deployed, at 30 days follow-up, and during any period of continued follow-up. Aneurysm-related mortality was defined as any death because of rupture or death within 30 days of the procedure.

Study population issues: Of the 221 patients, 199 (90%) were considered high-risk by the American Society of Anesthesiology classification (score 3 to 4). Conical shape was the most frequent hostile neck condition, noted in 82 (38%) patients.

Key efficacy findings

Number of patients analysed: 221

Technical success

- Initial technical success=89.1% (197/221); 23 patients had type 1a endoleak after the procedure, all of which were managed conservatively. One of these patients died immediately after the operation because of multi-organ failure.

- 30-day technical success=95.5% (211/221); 4 patients had persistent type 1a endoleak and 2 had new type 1a endoleaks that had not been identified at the end of the index procedure. Of these 6 patients, 2 had aortic banding by open surgery, 3 had endovascular treatment with a large balloon-expanding stent and 1 had conservative management.

- Follow-up technical success=95.5% (211/221); 5 patients had new type 1a endoleaks, 1 had reappearance of a spontaneously sealed type 1a endoleak and 4 patients had new type 1b endoleaks. Of these 10 patients, 6 had endovascular treatment, 1 had open surgery and 3 had conservative management.

Freedom from type 1a endoleak at 24 months

- All patients=94%
- Primary group=96%
- Revision group=86%, p=0.036

Reintervention at 24 months

- Freedom from neck related reinterventions=98%
- Freedom from any reintervention=87%

Survival at 2 years

- Freedom from all-cause mortality=89%
- Freedom from aneurysm-related mortality=98%

Aneurysm sac evolution

- Sac size before procedure=66.3mm ± 15.1
- Sac size after procedure= 61.7mm ± 17.5, p<0.001

- In the 180 patients with at least 6 months of imaging follow-up, 41.1% showed sac regression, 51.1% remained stable and sac growth was reported in 7.8% of patients.

Key safety findings

Endoanchor deployment issues

- Fractures, n=4 (no treatment)
- Losses, n=4 (2 were snared, 1 was caged and 1 was left in main endograft body)
- Twisted device, n=2 (catheter was changed)

None of these caused any type of intraoperative or follow-up complication or failure.

Mortality

- Aneurysm-related deaths, n=4 (within 30 days)
    - Multiorgan failure, n=1
    - Sepsis, pneumonia, n=2
    - Endograft infection, n=1

- Non-aneurysm-related deaths, n=21
    - Neoplasm, n=8 (at 10, 11, 14, 14, 15, 42, 43 and 44 months)
    - Cardiac, n=4 (at 5, 11, 23 and 49 months)
    - Sepsis, n=2 (at 2 and 9 months)
    - Respiratory, n=1 (at 12 months)
    - Unknown cause, n=6 (at 3, 16, 20, 31, 34 and 38 months)

Study 6 Mehta M (2014)

Study details

Study type	Single-arm study
Country	US (25 sites)
Recruitment period	2007 to 2009
Study population and number	n=155 Patients who had EVAR with endoanchors for abdominal aortic aneurysm
Age and sex	Mean 73 years; 93.5% male
Patient selection criteria	Inclusion criteria included: age 21 years or above; male or nonpregnant female; infrarenal abdominal aortic aneurysm with a maximum diameter 4.5 cm or more, at least 12 mm length of nonaneurysmal proximal neck, a proximal neck internal diameter between 19 and 29 mm, an internal diameter at the aortic bifurcation 18 mm or more, an angle of 60 degrees or less relative to the long axis of the aorta; bilateral iliac artery distal fixation sites 10 mm or more in length; the resultant repair should preserve patency in at least 1 hypogastric artery; bilateral iliac arteries with an internal diameter between 9 and 20 mm; bilateral femoral/iliac arteries with morphology (minimal thrombus, calcium, or tortuosity) compatible with standard vascular access techniques, and vessel size must accommodate a 16F (5.3 mm) or 18F (6.0 mm) delivery system; candidate for elective surgical repair; life expectancy more than 2 years. Exclusion criteria included: myocardial infarction within past 10 weeks; active systemic infection; ruptured or leaking, mycotic or inflammatory abdominal aortic aneurysm; connective tissue disorders; concomitant thoracic or thoracoabdominal aortic aneurysms; previous abdominal aortic aneurysm repair; patients with a body habitus that would prevent imaging required by the study; significant comorbid conditions that, in the opinion of the investigator, pose undue risk of general anaesthesia or endovascular surgery; patient requires additional planned major procedure at the time or within 30 days; dialysis dependent renal failure or creatinine concentration >2.5 mg/dL; allergy to or intolerance of radiopaque contrast agents that cannot be adequately pretreated or would prevent imaging required by the study; known sensitivity or allergy to polyester, nickel, titanium, tantalum, chromium, molybdenum, or cobalt; patients who cannot discontinue oral anticoagulation or antiplatelet therapy at the time of the study procedure; history of bleeding diathesis or hypercoagulable condition; thrombus, calcification, or plaque 2 mm or more in thickness or 50% or more (180-degree) continuous coverage of the vessel circumference in the intended seal zone; irregularly shaped calcification or plaque that may compromise the fixation and sealing at the proximal or distal implantation sites.
Technique	Device: Aptus endograft and EndoAnchors (Aptus Endosystems, US) The median number of endoanchors was 5 per patient (range 0 to 14)
Follow up	Median 3.4 years (IQR 3.1 to 3.8 years)

Conflict of interest/source of funding	1 author is a consultant for Aptus,1 is an adviser to Abbot, Gore, and Trivascular, 1 receives research funding for clinical trials participation from Medtronic, Gore, Cook, Endologix, Trivascular, Cordis, and Aptus and is a consultant for Medtronic, Gore, Endologix, and Aptus, 1 receives an honorarium from and is a speaker for Gore, Trivascular, Aptus, Endologix, and IDEV and receives research funding for clinical trial participation from Gore, Medtronic, Aptus, Lombard, Bolton, Abbott, Cordis, Terumo, ev3, Trivascular, Maquet, and Harvest, 1 is a speaker for Medtronic and Gore and participates in clinical trials for Gore, Medtronic, and Aptus, and 1 is a consultant for Gore.

Analysis

Follow-up issues: Patients had CT scans at 1, 6, and 12 months and then yearly thereafter through 60 months after implantation.

Study design issues: Prospective, multicentre, single-arm investigational device exemption trial. The primary safety end point of the study was the percentage of patients experiencing 1 or more major adverse events within 30 days of the index procedure (including death, myocardial infarction, stroke, renal failure, respiratory failure, or paralysis). The primary effectiveness end point of the study was the composite of delivery success and absence of type 1 or type 3 endoleaks needing intervention after the index procedure, migration, open surgical conversion, or aneurysm rupture within 1 year of the index procedure. Delivery success was defined as successful implantation of the endograft with a main body and 2 iliac limbs and delivery of at least 2 endoanchors at an appropriate treatment site within the proximal aortic neck. Aneurysm sac enlargement or shrinkage was defined when the maximum sac diameter changed by more than 5 mm, and migration was defined by endograft stent movement of more than 10 mm, both relative to the 30-day CT scan as read by the core laboratory. For the sample size calculation, the estimated major adverse events rate at 30 days was 4.6% for the primary safety end point, and the estimated treatment success for the effectiveness end point was 90.3%.

Study population issues: Aneurysms ranged in size from 4.2 to 9.4 cm, with a mean of 5.4 cm. The mean proximal aortic neck length was 22.1 mm (range 2 to 50 mm). The proximal neck length was less than 12 mm and less than 10 mm in 17% and 12% of patients, respectively. The mean infrarenal neck angulation was 32.1 degrees (range 3.1 to 71.7 degrees).

This study is also included in the systematic reviews by Qamhawi (2020) and Karaolanis (2020).

Key efficacy findings

Number of patients analysed: 155

Technical success

- Successful device delivery=98.7% (153/155); 1 patient had conversion to open surgical repair before the placement of endoanchors after unsuccessful cannulation of the contralateral gate. The second patient had a different endovascular device after misdeployment of the main body of the endograft.

Treatment success

- Primary effectiveness endpoint at 1 year=97.4% (151/155)
- Type 1 and type 3 endoleaks were each reported in 1 patient within the first year of follow-up.

- Type 2 leaks at 30 days=32.9% (49/149)
- Type 2 leaks at 1 year=17.6% (23/131)
- Endograft migration more than 1 cm=3.2% (5/155)

Overall survival

- 1 year=96.8%
- 2 years=96.1%
- 3 years=91.6%

- Freedom from aneurysm related mortality at 1 year=99.4%

Aneurysm sac diameter change, n (%)

Diameter change	6 months, n=140	1 year, n=131	2 years, n=107	3 years, n=82
decrease by more than 5 cm	62 (44.3)	79 (60.3)	78 (72.9)	67 (81.7)
5 cm or less ('no change')	77 (55.0)	50 (38.2)	26 (24.3)	12 (14.6)
increase by more than 5 cm	1 (0.7)	2 (1.5)	3 (2.8)	3 (3.7)

Reinterventions

- 74 (47.7%) patients had a total of 122 secondary interventions, 92 of which were in patients with thrombus-related events.

Key safety findings

Mortality

- 30-day mortality=0.6% (1/155); cardiac death 18 days after an index procedure complicated by rupture of an iliac artery during balloon angioplasty of a graft limb.
- There was 1 additional aneurysm-related death beyond 3 years caused by haemorrhagic stroke, adjudicated to be related to warfarin prescribed to treat a pulmonary embolism after an abdominal aortic aneurysm-related reintervention.

Major adverse events within 30 days, 1 year and 3 years of index procedure, n (%)

Event	30 days	1 year	3 years
Death	1 (0.6)	5 (3.2)	15 (9.7)
Myocardial infarction	2 (1.3)	7 (4.5)	10 (6.5)
Stroke	0 (0)	3 (1.9)	7 (4.5)
Renal failure	0 (0)	2 (1.3)	6 (3.9)
Respiratory failure	0 (0)	1 (0.6)	3 (1.9)
Paralysis	0 (0)	0 (0)	0 (0)
Any major adverse event	3 (1.9)	14 (9.0)	30 (19.4)

Thrombus-related events

- 62 (40.0%) patients had a total of 114 adverse events; in 98.4% (61/62) of these patients, the event was thrombus related.
- 32 (20.6%) patients had a total of 49 device-related thrombotic events within 1 year of implantation and 56 patients (36.1%) had 104 device-related thrombotic events within 3 years. Median time from implantation to first event in affected patients was 355 days (IQR 176 to 691 days; range 17 to 1477 days).
- Limb occlusion=4.5% (7/155) at 1 year and 7.7% (12/155) at 3 years.
- Distal embolic events linked to the endograft=9.7% (15/155) at 1 year and 14.8% (23/155) at 3 years.
- Nonocclusive thrombus identified by imaging=9.7% (15/155) at 1 year and 21.3% (33/155) at 3 years.

A root cause analysis of thrombus-related events identified small, out-of-specification docking limbs with graft infolding and high local shear, resulting in thrombus formation within the endograft with subsequent distal embolisation in some patients.

The authors noted that the device was subsequently modified to reduce the rate of thrombus-related events.

Study 7 Masoomi R (2019)

Study details

Study type	Case series (MAUDE database)
Country	US
Recruitment period	2011 to 2017
Study population and number	n=229 separate reports describing possible adverse events Device-related adverse events associated with the use of endoanchors in endovascular aneurysm repair
Age and sex	Not reported
Patient selection criteria	All events involving the name “Aptus Heli-FX EndoAnchor system” were identified on the MAUDE database. Four reports involving thoracic aortic aneurysm repair were excluded.
Technique	Endoanchoring device: Aptus Heli-FX EndoAnchor system (Medtronic Vascular, US).
Follow up	Not reported
Conflict of interest/source of funding	None

Analysis

Study design issues: The main aim of the study was to assess the safety of EndoAnchor use in routine clinical practice by extracting data from the publicly available MAUDE database. Information submitted to the MAUDE database has several limitations, including the possibility of inaccurate or incomplete data, and underreporting. There is a time delay between the event date and report date, which can lead to underestimation of overall incidence of adverse events. For these reasons, the MAUDE database cannot be used to accurately determine the true incidence of adverse events. Two members of the team reviewed all reports independently and reports were categorised as residual endoleak, dislodgement or fracture of the EndoAnchors, air embolism, guide or applier malfunction, and other adverse events. Duplicate reports and those deemed unrelated to the device were not included.

An estimate of the number of device systems used during the study period was obtained through direct correspondence with the manufacturer. This figure was quoted as around 7,000 systems used.

Study population issues: There was no information on aortic neck anatomy or patients’ characteristics.

Other issues: the paper states that there were 229 separate reports, but the reported percentages appear to have used 213 as the denominator.

Key safety findings

Number of separate reports on MAUDE database=229, estimated total device systems used=7,000

Reported events by type

- Failure to resolve or recurrence of a type 1A endoleak, n=123 (58% of reports; 1.7% of estimated total device systems used)
- Device dislodgement or fracture, n=65 (31% of reports; 0.9% of estimated total device systems used). The fractured device embolised to the renal artery in 2 cases, hypogastric artery in 1 case, and the flow divider of the endograft in 1 case.
- Air embolism, n=5 (0.07% of estimated total device systems used)
- Guide or applier malfunction, n=20 (0.3% of estimated total device systems used)
- There were 27 deaths reported during index hospitalisation or during follow up. Of those, 15 were of unknown aetiology or considered to be unrelated to the index procedure, and 12 reports were thought to be related to the index EVAR procedure rather than EndoAnchor use. There was 1 report where multiple tiny holes were seen at the site of EndoAnchor insertion in fabric at the time of explant (and these were thought by the reporting physician to have contributed to worsening endoleak).

No long-term clinical consequences were reported from the air embolisms or guide malfunctions.

The authors noted that most adverse events occurred in non-elective cases.

Study 8 Goudeketting S (2019)

Study details

Study type	Case series (subset of ANCHOR registry data)
Country	US and the Netherlands
Recruitment period	Not reported
Study population and number	n=86 (61 primary and 25 revision) Patients who had therapeutic use of endoanchors
Age and sex	81% male
Patient selection criteria	Patients from the ANCHOR registry were included in this study only if the indication for endoanchor use was to treat a type 1a endoleak and the first postprocedural CT angiography scan was of sufficient quality. Patients were excluded when aortic extension cuffs were implanted at the time of endoanchor implantation. The primary arm consisted of patients treated for an intraoperative type 1a endoleak; the revision arm comprised those with endoanchor implant use as a secondary intervention for type 1a endoleak or endograft migration after EVAR.
Technique	Device: Heli-FX EndoAnchor System (Medtronic Vascular, US) 580 endoanchor implants were used.
Follow up	1 month
Conflict of interest/source of funding	This research received a restricted grant from Medtronic, Inc. Three authors are consultants and on the Scientific Advisory Board for Medtronic, Inc.

Analysis

Study design issues: The study used a subset of patients from the ANCHOR global registry. The aim was to analyse the relationship between endoanchor deployment and successful resolution of type 1a endoleaks, including their distribution along the circumference of the neck, penetration depth into the aortic wall, and angle of penetration. The study population was divided into a nonsuccessful and successful cohort based on persistence of type 1a endoleak after treatment with endoanchor implants at 1-month follow up. Maldeployment was investigated for each endoanchor implant and defined as implants deployed above the fabric or in a gap more than 2 mm between the endograft and aortic wall (endograft malapposition) because of thrombus more than 2 mm in the infrarenal neck or positioning of the endoanchor implant below the aortic neck.

Study population issues: Median preoperative neck diameter was 26.5 mm (IQR, 24.2 to 28.8 mm).

Key efficacy findings

Number of patients analysed: 86

- 62% (53/86) of endoleaks had resolved at the 1-month CT angiography study.

- 17 (27.9%) patients in the primary arm and 16 (64.0%) in the revision arm had a persistent type 1a endoleak.
- 332 and 248 endoanchor implants were deployed in the cohorts with and without procedural success, respectively.
- The median number of implants was 6 (IQR, 4 to 8) per patient in the 53 patients with successful resolution of the type 1a endoleak and 8 (IQR, 4 to 10) in the 33 patients with a persistent endoleak (p=0.06).
- After exclusion of the maldeployed implants, 87.4% of the implants in the successful group had a good penetration compared with 68.8% in the cohort without procedural success.

Key safety findings

- Maldeployment=29% (170/580) of endoanchor implants
- In 33 patients of the successful group, a median of 1 [IQR, 1 to 3] implant was maldeployed. In the 21 patients with a persistent type 1a endoleak, a median of 4 [IQR, 3 to 6] implants were maldeployed.
- 7 (1%) implants were deployed above the fabric and 163 (28%) implants were deployed in a ≥2-mm gap between the endograft and aortic wall.
- The amount of implants with good, borderline, and no penetration was still statistically significantly different between the procedural success and failure groups after exclusion of implants with maldeployment (success: 235 [87.4%], 14 [5.2%], and 20 [7.4%]; type 1a endoleak: 97 [68.8 %], 18 [12.8%] and 26 [18.4%]; p<0.001).

The authors noted that maldeployment of endoanchor implants may be overcome by careful preoperative planning to identify the apposition zone and to prevent deployment in a gap more than 2 mm between the aortic wall and endograft.

Study 9 Rosu C (2021)

Study details

Study type	Case report
Country	Canada
Recruitment period	Not reported
Study population and number	n=1
Age and sex	72 year old male
Patient selection criteria	Not applicable
Technique	Device: Heli-FX EndoAnchor System (Medtronic Vascular, US)
Follow up	to hospital discharge (2 weeks after intervention)
Conflict of interest/source of funding	None

Key safety findings

An endoanchoring system was used to deploy helical anchors in the distal aortic arch during a procedure to correct a type 1A endoleak following Zone 2 thoracic endovascular aortic repair of a saccular proximal descending thoracic aorta aneurysm. The patient developed ST-segment elevations and severe hypotension moments after the endoanchors were deployed at the proximal edge of the endograft. Transoesophageal echocardiogram showed severe right ventricular hypokinesis and a large amount of air in the ascending aorta.

The table was put into Trendelenburg position. After 10 minutes of haemodynamic support and with air disappearing from the ascending aorta, the patient's haemodynamics stabilised. Significant systemic hypertension was present for several minutes. At the end of the procedure, the patient was extubated and emerged from general anaesthesia with unmanageable agitation despite administration of sedatives. There was a new paresis of the right upper limb. The patient was reintubated and a CT scan of the head showed slight oedema of the left posterior brain with no evidence of air embolism. CT angiography showed no cerebral vessel occlusions. The thoracic aortic aneurysm sac was thrombosed with no evidence of endoleak. The patient was discharged from the hospital 2 weeks later with minimal sequelae.

Validity and generalisability of the studies

- No randomised controlled trials were identified.
- Studies included data reported from the UK.
- There is some patient overlap between the studies. Data from the ANCHOR registry have been reported in numerous publications.
- In the systematic review, most patients had favourable aortic neck characteristics and the results may not be generalisable to patients with more challenging anatomy (Qamhawi, 2020).
- Different stent grafts have been used, which may have different safety and efficacy profiles. For example, migration rates may be lower with newer generation stent grafts.
- One study used an earlier version of an endograft and endoanchoring system and reported high rates of thrombus-related events associated with the endograft. The authors noted that newer endograft devices have been modified to reduce the rate of thrombus-related events (Mehta, 2014). This study also had extensive inclusion and exclusion criteria that would have excluded most patients with hostile aortic neck anatomy.
- Two studies reported median follow-up periods longer than 2 years (Valdivia, 2021; Mehta, 2014).

Existing assessments of this procedure

A European Network for Health Technology Assessment report on 'Prophylactic or therapeutic use of endoanchoring systems in endovascular aortic aneurysm repair (EVAR/REVAR)' was published in November 2019 (Agencia de Evaluación de Tecnologías Sanitarias-Instituto de Salud Carlos III, 2019). The report concluded:

'Based on the results from observational studies, and within the limitations of the low-quality evidence available, the data suggest that the use of Heli-FX ™ EndoAnchor ™ in EVAR patients (prophylactically or as part of endograft migration or type I endoleak treatment) would be safe in the midterm follow-up for those presenting unfavourable neck anatomy and probably safe over long-term

follow-up for those with friendly neck anatomies. However, comparative data on standard endovascular therapy are not currently available. We cannot form any conclusions regarding the safety of Heli-FX ™ EndoAnchor ™ in TEVAR patients.

In terms of effectiveness, again the evidence precludes any firm conclusions as to whether the use of endoanchors in EVAR/TEVAR procedures results in better outcomes. Globally, the information compiled on critical outcomes (rate of type I endoleaks or migration, rate of reintervention, rate of aneurysm rupture or rate of aneurysm-related mortality), although of very low quality, would suggest effectiveness of the device. Nonetheless, evidence from high-quality comparative studies remains lacking. Results should be compared with treatment regimens without the Heli-FX ™ EndoAnchor™ system in randomised controlled trials for most of the critical and important outcomes.'

Related NICE guidance

Below is a list of NICE guidance related to this procedure.

Interventional procedures

- Laparoscopic repair of abdominal aortic aneurysm. NICE Interventional procedures guidance 229 (2007). Available from http://www.nice.org.uk/guidance/IPG229
- Stent-graft placement in abdominal aortic aneurysm. Interventional procedures guidance 163 (2006). Available from http://www.nice.org.uk/guidance/IPG163
- Endovascular stent–graft placement in thoracic aortic aneurysms and dissections. Interventional procedures guidance 127 (2005). Available from http://www.nice.org.uk/guidance/IPG127

Medical technologies

- E-vita open plus for treating complex aneurysms and dissections of the thoracic aorta. NICE Medical technologies guidance 16 (2013; last updated: October 2018). Available from http://www.nice.org.uk/guidance/MTG16

NICE guidelines

- Abdominal aortic aneurysm: diagnosis and management. NICE guideline 156 (2020). Available from http://www.nice.org.uk/guidance/NG156

Additional information considered by IPAC

Professional experts' opinions

Expert advice was sought from consultants who have been nominated or ratified by their professional Society or Royal College. The advice received is their individual opinion and is not intended to represent the view of the society. The advice provided by professional experts, in the form of the completed questionnaires, is normally published in full on the NICE website during public consultation, except in circumstances but not limited to, where comments are considered voluminous, or publication would be unlawful or inappropriate.

Two professional expert questionnaires for prophylactic or therapeutic use of endoanchoring systems in endovascular aortic aneurysm repair were submitted and can be found on the NICE website.

Patient commentators' opinions

NICE's Public Involvement Programme was unable to gather patient commentary for this procedure.

Company engagement

A structured information request was sent to 1 company who manufactures a potentially relevant device for use in this procedure. NICE received 1 completed submission. This was considered by the IP team and any relevant points have been taken into consideration when preparing this overview.

Issues for consideration by IPAC

Ongoing trials:

- Aneurysm Treatment Using the Heli-FX™ EndoAnchor™ System Global Registry (ANCHOR); NCT01534819; cohort study; n=1,090; estimated end date Dec 2024.

- Physician Initiated Trial Investigating ESAR (EVAR Plus Heli-FX EndoAnchors) and FEVAR for the Treatment of Aortic Aneurysms With Short Infrarenal Aortic Neck; NCT04503395; Austria, France, Germany, The Netherlands and Spain; RCT; n=204; estimated end date June 2025

References

1. Qamhawi Z, Barge TF, Makris GC et al. (2020) Editor's Choice - Systematic review of the use of endoanchors in endovascular aortic aneurysm repair. European Journal of Vascular and Endovascular Surgery 59: 748–56
2. Karaolanis G, Antonopoulos CN, Koutsias S et al. (2020) Outcomes of endosutured aneurysm repair with the Heli-FX EndoAnchor implants. Vascular 28: 568–76
3. Muhs BE, Jordan W, Ouriel K et al. (2018) Matched cohort comparison of endovascular abdominal aortic aneurysm repair with and without EndoAnchors. Journal of Vascular Surgery 67: 1699–1707
4. Jordan WD Jr, Mehta M, Varnagy D et al. (2014) Results of the ANCHOR prospective, multicenter registry of EndoAnchors for type Ia endoleaks and endograft migration in patients with challenging anatomy. Journal of Vascular Surgery 60: 885–92e2
5. Valdivia AR, Gandarias C, Chaudhuri A et al. (2021) Endovascular aortic repair with EndoAnchors demonstrate good mid-term outcomes in physician-initiated multicenter analysis-The PERU registry. Vascular doi:10.1177/1708538121992596
6. Mehta M, Henretta J, Glickman M et al. (2014) Outcome of the pivotal study of the Aptus endovascular abdominal aortic aneurysms repair system. Journal of Vascular Surgery 60: 275–85
7. Masoomi R, Robinson A, Hacker E et al. (2019) Safety of EndoAnchors in real-world use: A report from the Manufacturer and User Facility Device Experience database. Vascular 27: 495–99
8. Goudeketting SR, van Noort K, Vermeulen JJM, et al. (2019) Analysis of the position of EndoAnchor implants in therapeutic use during endovascular aneurysm repair. Journal of Vascular Surgery 69:1726–35
9. Rosu C, Ruz R, Elkouri S et al. (2021) Caution: air embolism related to Heli-Fx EndoAnchor System in zone 2 thoracic aneurysm repair. Journal of Endovascular Therapy doi: 10.1177/15266028211062562
10. Agencia de Evaluación de Tecnologías Sanitarias-AETS-ISCIII, Republika Slovenija Ministrstvo za Zdravjel. Prophylactic or therapeutic use of endoanchoring systems in endovascular aortic aneurysm repair (EVAR/TEVAR). Collaborative Assessment: EUnetHTA; 2019. Report No.: OTCA20

Literature search strategy

Databases	Date searched	Version/files
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	12/01/2022	Issue 1 of 12, January 2022
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	12/01/2022	Issue 12 of 12, December 2021
International HTA database (INAHTA)	12/01/2022	-
MEDLINE (Ovid)	12/01/2022	1946 to 2022 January 11
MEDLINE In-Process (Ovid)	12/01/2022	1946 to 2022 January 11
MEDLINE Epubs ahead of print (Ovid)	12/01/2022	January 11
EMBASE (Ovid)	12/01/2022	1974 to 2022 January 11
EMBASE Conference (Ovid)	12/01/2022	1974 to 2022 January 11

Trial sources searched

- Clinicaltrials.gov
- ISRCTN
- WHO International Clinical Trials Registry

Websites searched

- National Institute for Health and Care Excellence (NICE)
- NHS England
- Food and Drug Administration (FDA) - MAUDE database
- Australian Safety and Efficacy Register of New Interventional Procedures – Surgical (ASERNIP – S)
- Australia and New Zealand Horizon Scanning Network (ANZHSN)
- General internet search

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

Literature search strategy

1 exp Aortic Aneurysm, Abdominal/ 20879
2 (EVAR or EVRAR or FEVAR or F-EAVAR or BEVAR or B-EVAR).tw. 4173
3 (aneurysm* adj4 (abdom* or thoracoabdom* or thoraco-abdom* or aort* or spontan* or juxtarenal* or juxta-renal* or juxta renal* or paraerenal* or para-renal* or

para renal* or suprarenal* or supra renal* or supra-renal* or short neck* or short-neck* or shortneck* or visceral aortic segment*)).tw. 40242
4 Aortic Rupture/ 10007
5 (AAA or RAAA).tw. 13517
6 (aort* adj4 (ruptur* or burst* or break* or split*)).tw. 8482
7 or/1-6 55548
8 Endoleak/ 1759
9 (endoleak* or perigraft*).tw. 5355
10 8 or 9 5565
11 7 and 10 4290
12 (Endosutur* or endostap* or Endoanchor* or endostitch*).tw. 377
13 ESAR.tw. 56
14 12 or 13 431
15 11 and 14 64
16 Helifx.tw. 4
17 heli-fx.tw. 20
18 endologix.tw. 111
19 Nellix.tw. 147
20 Endo Stitch.tw. 29
21 or/16-20 277

Appendix

The following table outlines the studies that are considered potentially relevant to the IP overview but were not included in the summary of the key evidence. It is by no means an exhaustive list of potentially relevant studies.

Single case reports have been excluded.

Additional papers identified

Article	Number of patients/ follow-up	Direction of conclusions	Reasons for non-inclusion in summary of key evidence section
Arko FR, Stanley GA, Pearce BJ et al. (2019) Endosuture aneurysm repair in patients treated with Endurant II/IIs in conjunction with Heli-FX EndoAnchor implants for short-neck abdominal aortic aneurysm. Journal of Vascular Surgery 70: 732–40	Cohort study n=70 FU=12 months	In this analysis of the short-neck cohort from ANCHOR, the procedure appears to be a safe and effective treatment option with a high technical success rate and low incidence of type 1a endoleaks and secondary interventions. The short-term outcomes suggest that it could be complementary to therapies currently available for treatment of hostile anatomy and a viable off-the-shelf endovascular treatment option for patients with short-neck abdominal aortic aneurysms, although long-term follow-up is critically important.	Subgroup analysis of ANCHOR registry, included in Karaolanis (2020) systematic review.
Avci M, Vos JA, Kolvenbach RR et al. (2012) The use of endoanchors in repair EVAR cases to improve proximal endograft fixation. The Journal of Cardiovascular Surgery 53: 419–26	Case series n=11 FU=mean 10 months	One endoanchor dislodged but was successfully retrieved using an endovascular snare. During follow-up there were no endoanchor-related complications or renewed migration of the endografts. Two patients had repeat intervention for persistent type 1a endoleak.	Small case series, included in Qamhawi (2020) systematic review.

Bail DH, Walker T, Giehl J (2013) Vascular endostapling systems for vascular endografts (T) EVAR—systematic review—current state. Vascular and Endovascular Surgery 47: 261–6	Systematic review	With endostaple systems, patients with difficult anatomic features and high risk can potentially be treated. These systems might reduce the high reintervention rates after endovascular aneurysm repair. Controlled randomised trials with larger number of patients are warranted.	More recent systematic reviews are included.
Chaudhuri A, Kim HK, Valdivia AR (2020) Improved midterm outcomes using standard devices and EndoAnchors for endovascular repair of abdominal aortic aneurysms with hyperangulated necks. Cardiovascular and Interventional Radiology 43: 971–80	Case series n=42 FU=mean 18.5 months	There was 1 death within 30 days. One patient had persistent type 1a endoleak, successfully banded. There was 6.8 mm sac size reduction ($p<0.001$). There were no other neck-related reinterventions, despite continued neck dilatation.	Small case series.
Deaton DH (2012) Improving proximal fixation and seal with the HeliFx Aortic EndoAnchor. Seminars in Vascular Surgery 25: 187–92	Review	The device's most immediate application will most likely be in the address of the failing endograft and in the extension of current technology to challenging anatomy where current endograft fixation technology has been demonstrated to have a higher rate of failure.	Review
Deaton DH, Mehta M, Kasirajan K et al. (2009) The phase I multicenter trial (STAPLE-1) of the Aptus Endovascular Repair System: Results at 6 months and 1 year. Journal of Vascular Surgery 49: 851–8	Case series n=21 FU=1 year	Three secondary interventions were done in 2 patients for limb thrombosis. There were no EndoStaple-related adverse events, device integrity failures, migrations, or conversions.	Small case series, included in Qamhawi (2020) and Karaolanis (2020) systematic reviews.

de Vries J-PPM, Ouriel K, Mehta M et al. (2014) Analysis of EndoAnchors for endovascular aneurysm repair by indications for use. Journal of Vascular Surgery 60: 1460-7e1	Cohort study (ANCHOR registry) n=319 FU=1 year	The most challenging subset was revision patients treated for type 1a endoleak; type 1a endoleaks were evident during follow-up in 34% (10/29) of patients. Sac regression >5 mm in patients with 1-year imaging was observed 39% (26/66) of patients and was highest in the primary prophylaxis subset (20/43; 47%).	A different publication from the same registry is included (Jordan W et al., 2014). Included in Qamhawi (2020) systematic review.
Donas KP, Torsello G (2010) Midterm results of the Anson Refix Endostapling Fixation system for aortic stent-grafts. Journal of Endovascular Therapy 17: 320–3	Case series n=8 FU=mean 18 months	There were no device failures, migrations, endoleaks, conversions, or secondary procedures.	Larger studies are included.
DuBois BG, Houben IB, Khaja MS et al. (2020) Thoracic endovascular aortic repair in the setting of compromised distal landing zones. The Annals of Thoracic Surgery. 111: 237–45	Case series n=51 (6 with endoanchors)	Thoracic endovascular aortic repair is a viable alternative for the treatment of thoracoabdominal aortic aneurysms in patients with compromised distal landing zones.	Endoanchors were only used in a small proportion of the patients.
Galiñanes EL, Hernandez-Vila EA, Krajce Z (2019) EndoAnchors minimize endoleaks in chimney-graft endovascular repair of juxtarenal abdominal aortic aneurysms. Texas Heart Institution Journal 46:183–8	Case series n=5 FU=11 to 18 months	It was feasible to use endoanchors with the chimney-graft technique to prevent type 1a endoleaks in the treatment of juxtarenal abdominal aortic aneuryms. Further studies are needed to validate this adjunctive technique and to determine its durability.	Small case series.
Galinanes EL, Hernandez E, Krajcer Z (2016) Preliminary	Case series n=9	Technical success=100% In 2 patients, type 1a endoleaks were noted before the	Small case series, included in

results of adjunctive use of endoanchors in the treatment of short neck and pararenal abdominal aortic aneurysms. Catheterization and Cardiovascular Interventions 87: e154-9	FU=mean 8 months	deployment of any endoanchors. In both cases, a final angiogram depicted resolution of the type 1a endoleak after insertion of the endoanchors. All the endografts remained patent and free from type 1a endoleaks. There were no adverse renal complications or mortality.	Qamhawi (2020) systematic review.
Giudice R, Borghese O, Sbenaglia G et al. (2019) The use of EndoAnchors in endovascular repair of abdominal aortic aneurysms with challenging proximal neck: Single-centre experience. JRSM Cardiovascular Disease 8: 1–8	Case series n=17 FU=median 13 months	Technical success=100% There were no aneurysm-related deaths or aneurysm ruptures, and all patients were free from reinterventions. CT-scan surveillance showed no evidence of type 1a endoleak, anchors dislodgement or stent-graft migration, with a mean reduction of aneurysm diameter of 0.4 mm (range 0 to 19); there was no sac growth or aortic neck enlargement in any case.	Small case series, included in Qamhawi (2020) systematic review.
Goudeketting SR, van Noort K, Vermeulen JJM et al. (2019) Analysis of the position of EndoAnchor implants in therapeutic use during endovascular aneurysm repair. Journal of Vascular Surgery 69: 1726–35	Cohort study n=86	In this subcohort of ANCHOR patients, almost 30% of the EndoAnchor implants had maldeployment, which may be prevented by careful preoperative planning and measured intraoperative deployment. If endoleaks are due to gaps bigger than 2 mm, EndoAnchor implants alone may not provide the intended sealing, and additional devices should be considered.	Subgroup analysis of ANCHOR registry.
Goudeketting SR, Wille J, van den Heuvel DAF et al. (2019) Midterm single-center results of endovascular aneurysm repair with additional EndoAnchors. Journal	Cohort study n=51 FU=median 24 months	Kaplan-Meier estimates of freedom from type 1a endoleak, proximal neck-related reinterventions, and aneurysm-related mortality at 2 years were 87.3%, 92.2%, and 94.0%, respectively	Larger studies are included.

of Endovascular Therapy 26: 90–100			
Goudeketting SR, van Noort K, Ouriel K et al. (2018) Influence of aortic neck characteristics on successful aortic wall penetration of EndoAnchors in therapeutic use during endovascular aneurysm repair. Journal of Vascular Surgery 68: 1007–16	Cohort study n=86	Adequate EndoAnchor penetration into the aortic wall is less likely when the aortic neck diameter is large or when the neck contains significant mural calcium. No penetration of the EndoAnchor was the only factor predictive of postprocedural type 1a endoleak.	Subgroup analysis of ANCHOR registry.
Ho VT, George EL, Dua A et al. (2020) Early real-world experience with EndoAnchors by indication. Annals of Vascular Surgery 62: 30–34	Case series n=37	Early experience suggests that endoanchors effectively treat intraoperative type 1a endoleaks and high-risk seal zones, with sac regression and no proximal endoleaks on follow-up. In patients treated for prior EVAR with postoperative type 1a endoleaks, fewer than half resolved after endoanchor attempted repair.	Small case series, included in Qamhawi (2020) systematic review.
Jordan WD Jr, de Vries J-PPM, Ouriel K et al. (2015) Midterm outcome of EndoAnchors for the prevention of endoleak and stent-graft migration in patients with challenging proximal aortic neck anatomy. Journal of Endovascular Therapy 22: 163–70	Cohort study n=208 FU=mean 14 months	Technical success=98% (204/208). The frequency of fracture was 0.3% (3/1118); there were no clinical sequelae associated with the fractures. Over the follow-up, 95% of patients were alive, and no deaths were attributable to EndoAnchors. There were no ruptures, migrations, or open surgical conversions. Aneurysm-related reinterventions were performed in 8 (4%) patients. Among 130 patients with postprocedure contrast CT studies, 2 had type 1a endoleaks. Aneurysm sac diameter decreased >5 mm in 43% of patients with CT scans at or beyond 1 year; 2% of	Subgroup analysis of ANCHOR registry (prophylactic use only)

		patients had sac enlargement >5 mm.	
Jordan WD Jr, Ouriel K, Mehta M et al. (2015) Outcome-based anatomic criteria for defining the hostile aortic neck. Journal of Vascular Surgery 61: 1383–90	Cohort study n=221	A limited number of independent anatomic variables are predictive of type 1a endoleak after EVAR, including aortic neck diameter and aortic neck length, whereas mural thrombus in the neck is protective.	Subgroup analysis of ANCHOR registry
Jordan WD, Mehta M, Ouriel K et al. (2016) One-year results of the ANCHOR trial of EndoAnchors for the prevention and treatment of aortic neck complications after endovascular aneurysm repair. Vascular 24: 177–86	Cohort study n=100 FU=1 year	6% (6/100) of patients had aneurysm-related reinterventions during follow up. There were no aneurysm ruptures. Freedom from type 1a endoleak was 95% in the Primary Arm and 77% in the Revision Arm (p=0.006). Aneurysm sacs regressed >5 mm within 1 year in 45% of the Primary cases and in 25% of the Revisions. Aneurysm expansion >5 mm occurred in 1 revision patient.	Subgroup analysis of ANCHOR registry
Kasprzak P, Pfister K, Janotta M et al. (2013) EndoAnchor placement in thoracic and thoracoabdominal stent-grafts to repair complications of nonalignment. Journal of Endovascular Therapy 20: 471–80	Case series n=6 FU=mean 11 months	A patient with thoracoabdominal aortic aneurysm with a fenestrated aortic arch stent-graft had multiple visceral and cerebral infarctions and died 4 weeks after the procedure. During follow-up, there was no stent-graft migration or EndoAnchor dislocation. There were no periaortic haematomas or side branch complications.	Small case series, included in Qamhawi (2020) systematic review.
Locham S, Mathlouthi A, Dakour-Aridi H et al. (2021) Favorable outcomes in octogenarians with hostile neck undergoing endovascular repair using EndoAnchors.	Cohort study (ANCHOR registry) n=461 FU=1 year	Despite a worse aortic neck anatomy, octogenarians undergoing EVAR using EndoAnchors showed acceptable short and long-term outcomes. The results of this study could expand the use of EVAR in octogenarians with hostile neck.	Analysis of ANCHOR registry data, focusing on patients aged 80 years and over.

Annals of Vascular Surgery 74: 194–203			
Ongstad SB, Miller DF, Panneton JM (2016) The use of EndoAnchors to rescue complicated TEVAR procedures. The Journal of Cardiovascular Surgery 57: 716–29	Case series n=54 FU=mean 9.6 months	Endoanchors were used for therapeutic indications in 32% of patients and for prophylactic indications in 68%. The overall initial technical success was 98%. There were no instances of graft migration. The overall endoleak rate was 5% with prophylactic use and 12% with therapeutic use. Aortic-related reintervention was needed in 14% of patients who had prophylactic placement and 24% of patients who had therapeutic placement; 1 reintervention was done for endoanchor failure.	Small case series, included in Qamhawi (2020) systematic review.
Perdikides T, Melas N, Lagios K et al. (2012) Primary endoanchoring in the endovascular repair of abdominal aortic aneurysms with an unfavorable neck. Journal of Endovascular Therapy 19: 707–15	Case series n=13 FU=median 7 months	Primary technical success=85% Perioperatively, there were 2 type 2 endoleaks, which needed no intervention. During follow-up, there were no further complications apart from an asymptomatic internal iliac artery occlusion and a non-lethal myocardial infarction at 9 months. The type 2 endoleaks spontaneously sealed. There was no endograft migration or loss of endoanchor integrity. There were no deaths.	Small case series, included in Karaolanis (2020) systematic review.
Perini P, Bianchini Massoni C, Mariani E, et al. (2019) Systematic review and meta-analysis of the outcome of different treatments for type 1a endoleak after EVAR. Ann Vasc Surg 60: 435–46	Systematic review n=714 (35 with endostapling)	Different treatments are available for type 1a endoleak, and the choice should be based on endoleak characteristics, aortic anatomy, and the patient's surgical risk.	Only a small proportion of patients had endostapling.

Reyes Valdivia A, Busto Suarez S, Duque Santos A et al. (2020) Evaluation of EndoAnchor aortic wall penetration after thoracic endovascular aortic repair. Journal of Endovascular Therapy 27: 240–7	Case series n=25 FU=mean 16.6 months	EndoAnchors have a higher risk of maldeployment in the arch, though this may be attributable to the small learning curve experience in this location. The best aortic wall penetration for this series was in the descending thoracic aorta, where EndoAnchors proved useful for distal endograft fixation during TEVAR.	Larger studies are included.
Reyes Valdivia A, Duque Santos A, Pitoulias G et al. (2020) Predictors of inadequate EndoAnchors aortic wall penetration for the Endosutured therapy in hostile neck patients. The Journal of cardiovascular surgery 61: 738–44	Case series n=43	EndoAnchors use in hostile neck anatomies should not be considered an easy approach for the endovascular technique, especially for therapeutic cases. An individual and specific case analysis counterbalancing inadequate use of the device in unexperienced users should be evaluated against the increased risk of proximal failure as in standard EVAR alone during hostile neck anatomy treatment.	Larger studies are included.
Reyes Valdivia A, Beropoulis E, Pitoulias G et al. (2019) Multicenter registry about the use of EndoAnchors in the endovascular repair of abdominal aortic aneurysms with hostile neck showed successful but delayed endograft sealing within intraoperative type Ia endoleak cases. Annals of Vascular Surgery 60: 61–69	Case series n=46 FU=12 months	The study shows that additional use of EndoAnchors can successfully improve the sealing of abdominal endografts in case of intraoperative type 1a endoleaks in hostile neck anatomies, representing a safe and effective endovascular alternative. However, meticulous radiological follow-up is necessary because complete resolution of all observed intraoperative type 1a endoleaks was not observed until the 12-month CT follow-up.	Larger studies are included.
Spanos K, Rohlffs F, Panuccio G et al. (2019) Outcomes of	Systematic review n=356	A multitude of techniques for endovascular repair for type 1a endoleak exists. No strong	More recent systematic

endovascular treatment of endoleak type Ia after EVAR: a systematic review of the literature. Journal of Cardiovascular Surgery 60:175–85		evidence supports one specific technique. The early and mid-term outcomes are encouraging in terms of type 1a endoleak resolution, mortality and morbidity rates.	reviews are included.
Tassiopoulos AK, Monastiriotis S, Jordan WD et al. (2017) Predictors of early aortic neck dilatation after endovascular aneurysm repair with EndoAnchors. Journal of Vascular Surgery 66: 45–52	Cohort study n=209	Aortic diameter and graft oversizing appear to be independent risk factors for early aortic neck dilatation. Endoanchors have a protective effect on neck dilatation at their usual level of deployment.	Subgroup analysis of ANCHOR registry, included in Karaolanis (2020)
van Noort K, Vermeulen JJM, Goudeketting SR et al. (2019) Sustainability of individual EndoAnchor implants in therapeutic use to treat type Ia endoleak after endovascular aneurysm repair. Journal of Endovascular Therapy 26: 369–77	Cohort study n=54 FU=median 13 months	Despite the small number of endoanchors analysed, this study showed that the sustainability of implants with initially good penetration is satisfactory at 1-year follow-up. The vast majority of endoanchor implants with good penetration initially remained in good position; <3% of implants became borderline or nonpenetrating, without any clinical consequence.	Subgroup analysis of ANCHOR registry.