**Migration and sac expansion as modes of mid-term therapeutic failure after endovascular aneurysm sealing – 295 cases at a single centre**

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**Article Highlights**

**Type of research:** Retrospective analysis of prospectively-collected data.

**Key findings:** Midterm outcomes are reported for 295 cases of endovascular aneurysm sealing (EVAS) using the Nellix device for abdominal aortic aneurysm. Therapeutic failure was seen in a total of 33.2% of cases. The most common mechanism for failure was stentgraft migration with type 1a endoleak and sac expansion. Complications leading to therapeutic failure were most commonly seen after 2 years of follow-up. The device has been voluntarily withdrawn by the manufacturer.

**Take home message:** The authors believe that the use of EVAS as a disruptive technology highlights the need for greater regulation and governance surrounding the adoption of new technologies.

**Table of contents summary**

This retrospective study analysed mid-term outcomes in 295 consecutive cases of endovascular aneurysm sealing at a single, large-volume aortic centre. Therapeutic failure was seen in one third of cases, most commonly due to stentgraft migration with type 1a endoleak and sac expansion.

**Abstract**

**Introduction**

Endovascular aneurysm sealing (EVAS) is a disruptive technology to treat abdominal aortic aneurysm (AAA). The use of sac filling rather than endograft fixation was designed to treat a wide range of aortic morphologies and reduce endoleaks. There are few data reporting outcomes beyond post-operative follow-up. This study reports outcomes up to five years for Nellix-EVAS.

**Methods**

Data were prospectively collected data for EVAS patients from the time of adoption of EVAS in 2013. All patients treated with the Nellix device are included in this study, and as such it reports on infrarenal, ruptured and iliac aneurysms, as well as the Nellix-in-Nellix application. Juxta-and suprarenal aneurysms were treated using the EVAS system with parallel grafts into the visceral vessels and are included. Therapeutic failure, a composite outcome of migration, sac expansion >5mm, type 1a/1b endoleak, and secondary aortic rupture, was the primary outcome, along with all-cause mortality, aneurysm-related mortality and reintervention rates.

**Results**

295 EVAS cases were undertaken between March 2013 and July 2018. Indications for treatment were infrarenal (n=185), juxta- and suprarenal (n=73), ruptured (n=18) and iliac (n=13) aneurysms. There were 15 reinterventions using the Nellix-in-Nellix application. In some cases, EVAS was used to salvage failing endovascular or open aneurysm repairs. Median follow-up was 2.42 years (interquartile range 1.07-3.57 years).

Therapeutic failure was observed in 98 of the 295 cases (33.2%) overall, and exceeded 50% in some subgroups. In 71 cases (24.1%) reintervention was performed, with reasons for no reintervention being mainly physiological. Complications leading to therapeutic failure were most commonly seen beyond 2 years of follow-up. There were 15 secondary ruptures (5.36%) and nine EVAS devices required explant either electively or for aortic rupture.

**Conclusion**

EVAS with the Nellix device has not met expectations, and early encouraging results have been eroded. The incidence of therapeutic failure has been high, occurring 2 years and beyond post implantation. The Nellix system has been voluntarily recalled by Endologix and the CE mark has subsequently been suspended(1). The adoption of EVAS as a disruptive technology highlights the need for cautious adoption of novel technologies, and the strict governance around such arrangements.

**Introduction**

Endovascular treatment of AAA has advantages over open surgical repair in terms of lower perioperative morbidity and mortality(2-4). Durability of endovascular repair and the need for lifelong surveillance remain concerns(5-7). Preoperative aortic morphology largely determines long-term outcome, with hostile neck anatomy being associated with higher rates of reintervention and poorer outcomes(8-12).

EVAS was presented as a novel concept and ‘disruptive technology’ in the treatment of AAA. The Nellix EVAS system (Endologix Inc, Irvine, CA, USA) comprises two balloon-expandable stents, each surrounded by a polymer-filled endobag, allowing anatomical sealing of the whole aneurysm sac; a move away from the traditional reliance on sealing at each end of a stentgraft(13). Early reports suggested that EVAS may allow the treatment of complex morphologies not otherwise amenable to endovascular repair, and may prevent endoleak formation(14). Early results using the Nellix device, following CE marking in 2013 showed promise(13, 15-17).

In 2016, EVAS FORWARD, an investigational device exemption trial, reported higher than expected rates of distal migration, type 1a endoleak and aneurysm sac expansion, leading to a refinement of the instructions for use (IFU) (18). The revised IFU addressed the proximal and distal seal zones, and thrombus burden within the aneurysm, with a view to reducing device migration (Appendix 1). The new IFU suggested EVAS would be most effective and durable in large AAA, with little thrombus and neck criteria similar to the IFU for other commercially-available EVAR stentgrafts. There are few published data reporting outcomes with respect to the revised IFU, however it is apparent that the morphological applicability was significantly reduced(19).

This study reports the mid-term outcomes of a large cohort of patients having undergone EVAS at a single large-volume aortic centre.

**Methods**

A retrospective review of prospectively-collected data regarding all patients who underwent treatment with the Nellix device, for all indications, between March 2013 and July 2018 is reported. It is thought to be the largest institutional series of this device worldwide and as such, important messages might be derived from the outcomes.

Outcomes are reported in accordance with reporting standards advised by the British Society for Endovascular Therapy(20). Guidance was sought from the UK National Research Ethics Service and ethical approval was not required as the analyses used data routinely collected for good clinical care. Patients were counselled regarding the experimental nature of the technique and gave consent for inclusion in this study.

All patients underwent preoperative computed tomographic (CT) scanning to assess aneurysm morphology and elective cases were discussed and plans agreed at the weekly aortic multidisciplinary meeting. Cases were planned using 3-dimensional reconstructive software (3mensio Medical Imaging BV, Bilthoven, Netherlands).

EVAS was undertaken when aortic morphology fell outside the IFU for conventional EVAR devices, but within the broader IFU for the Nellix device. All infrarenal EVAS cases took place before the IFU revision in December 2016. As with many new technologies, as experience and confidence grew within our unit and globally, more challenging aneurysms were treated, supported by promising early results (13, 15-17). EVAS cases were undertaken by 3 main operators in our institution, using identical operating procedures. Other than out of hours, all cases were undertaken with 2 consultant surgeons operating together.

Early in the study, some cases were treated with EVAS rather than fenestrated EVAR or EVAR with chimney grafts (ChEVAR), due to patients being unfit for FEVAR, their aneurysms being deemed morphologically unsuitable by the manufacturers, or time pressures for symptomatic aneurysms requiring an off-the-shelf solution. ChEVAS was planned where patients were unfit for open surgery, required repair sooner than a custom-made stent could be manufactured, or where the morphology was not considered compatible with FEVAR, most commonly because of severe angulation of the aortic neck or tortuosity of the access vessels or neck.

Reinterventions for type 1a endoleaks evolved during this study. Initially, treatment was embolisation with glue and coils(21, 22). As stent migration became apparent as a cause of type 1a endoleak, the use of the Nellix-in-Nellix (NINA) application(23) with or without chimney grafts (ChNINA) was used increasingly to develop an adequate proximal sealing zone. ChEVAS and ChNINA cases were planned to obtain a proximal sealing zone of at least 15 mm of parallel-sided aorta, with a diameter of 20-30 mm. Therefore, the number of parallel grafts required ranged from one to three. A number of patients underwent graft explanation for endoleak.

Our EVAS technique was refined as institutional experience grew and complications were reported globally. Follow-up involved both CT and ultrasound duplex, postoperatively, at 3, 6 and 12 months and annually thereafter. Clinical follow-up was at 6 weeks postoperatively, at which point patients were discharged to surveillance if appropriate. Follow-up CT scans were reviewed by both a specialist aortic interventional radiologist as well as the implanting surgeons. All scans were re-reviewed as part of our enhanced surveillance programme, detailed below.

Following global reports in late 2017 of higher than anticipated failure rates, all surviving patients, their general practitioners and referring vascular units were contacted in February 2018 and invited for enhanced surveillance, including CT angiogram and further clinical follow-up. This formed part of the UK National Health Service “Duty of Candour” responsibility. These results have been shared with the UK Medicines and Healthcare products Regulatory Agency (MHRA).

In accordance with consensus reporting standards, deaths occurring within 30 days of the procedure were considered aneurysm-related. Endoleaks are described according to established definitions(24). The term “therapeutic failure” was defined as a composite measure of graft migration >5mm from original implantation, sac expansion >5mm, types 1a and 1b endoleak or secondary rupture(25). Reintervention was defined as any procedure undertaken to maintain aneurysm exclusion or ensure distal perfusion, including graft explantation.

Normally distributed continuous variables are expressed as mean ± standard deviation, and those not normally distributed are expressed as median and interquartile range (IQR). Categorical variables are expressed as numbers with percentages. Differences between cases treated on and off IFU were assessed using the χ2 or Fisher exact test where appropriate. A P-value less than 0.05 was taken to signify statistical significance. Kaplan-Meier estimates were used to demonstrate freedom from events, with Breslow and log-rank tests being used to analyse differences between curves. Statistical analysis was undertaken using SPSS (SPSS Inc., Chicago, IL) and GraphPad (GraphPad Software Inc., La Jolia, CA). Data were censored on 7 October 2018.

**Results**

Between March 2013 and July 2018, 295 EVAS cases were performed in 280 patients. The median follow-up time was 2.4 years (IQR 1.1-3.6 years).

Attempts were made to contact all surviving patients in February 2018. For 19 patients it was not possible to get up to date CT imaging (i.e. within 12 months). Of these, 14 were referred from other centres and being followed up locally, and 5 patients local to our unit have not attended for CT scanning despite repeated attempts at contacting them directly and via local hospital and community medical services. NHS data allow us to interrogate whether they are still alive, and, to the best of our knowledge, these 19 patients are, although we cannot comment specifically on their graft status.

The median age was 74.6 years (IQR 70-81 years). 85.1% were male. Median aortic diameter was 62 mm. (IQR 58.5-69.0 mm). Baseline characteristics are presented in Table 1. The EVAS procedures were mainly infrarenally-placed devices or ChEVAS in elective and non-elective settings (appendix 2). Smaller numbers of NINA, iliac aneurysm and ruptured aneurysm repairs were undertaken.

Across the whole cohort, in all morphologies, 61(20.7%) cases were undertaken on a non-elective basis, 18/61 (29.5%) were for a ruptured aneurysm. Of the 185 infrarenal EVAS cases, 11 treated mycotic aneurysms, 8 treated failing bifurcated EVAR and 4 treated complications of open aneurysm repair. Of those patients undergoing ChEVAS, 2 had declined open repair, 12 had a symptomatic or ruptured infrarenal aneurysm and 48 were morphologically unsuitable for a custom-made device. These applications of the EVAS procedure were outside the IFU, but were undertaken as this procedure was considered to be the best endovascular option for these patients who were unfit for open repair.

**Overall cohort and mode of presentation**

Across all indications and modes of presentation, 30-day mortality after EVAS was 3.73%. Six of 11 who died within 30 days had presented with ruptured aneurysms, 3 developed bowel ischaemia postoperatively, 1 patient developed renal haemorrhage following cannulation of the left renal artery during a ChEVAS procedure, and 1 patient died of multi-organ failure following endobag rupture and intravascular polymer leak. In the cases of mesenteric ischaemia, there was no evidence of endobag prolapse encroaching on the ostia of the visceral vessels.

Across the whole cohort, therapeutic failure was observed in 98 cases (33.2%), representing 14.28 graft failures per 100 patient-years of follow-up. This was more prevalent 2 years or more after EVAS implantation (Figure 1). Freedom from therapeutic failure at median follow-up of 2.42 years was 77.3%. The overall incidence of type 2 endoleaks was 3.4%

Secondary aneurysm rupture was seen in 16 cases (5.4%) or 2.33 ruptures per 100 patient-years; 2 of these patients had originally presented with a ruptured aneurysm. 14 patients (87.5%) had no detected surveillance abnormality on imaging prior to presentation with secondary rupture. Of those 2 who had evidence of surveillance abnormality, one had a 5 mm increase in aneurysm sac size with no associated endoleak detected at any stage, the other patient had a known type 1a endoleak but had become acutely medically unwell since their surgery and was deemed not fit for intervention. Of these, 9 patients survived, with 8 having undergone reintervention (5 device explantations, 1 proximal extension, 1 proximal and distal extension and 1 embolisation of type 1a endoleak). The remaining patient had a contained rupture and was not fit for further reintervention but remains alive, with a palliative course of action having been agreed with the patient. Freedom from rupture at median follow-up was 96.4% for all types of presentations, including those presenting with initial aortic rupture. Type 1a endoleak was significantly associated with secondary rupture (P=0.011), whereas in the absence of type 1a, sac expansion, stent migration and types 1b and 2 endoleak did not show a significant association with secondary aneurysm rupture.

In cases of sac expansion, there were significant associations with stent migration, types 1a and 1b endoleak (P<0.0001, <0.0001 and 0.030 respectively) but not with type 2 endoleak.

Kaplan-Meier survival estimates of freedom from complication demonstrated no differences between those treated electively and non-electively (Table 2). There were no significant differences in the underlying causes of therapeutic failure, or of the composite measure of therapeutic failure, between elective and non-elective admissions. Overall incidence of all-cause and aneurysm-related mortality (ACM and ARM) were significantly lower in those treated electively (p<0.0001 and p=0.001 respectively).

Graft-related complications occurred in greater numbers 2 years or more after implantation. Reintervention was performed in 71 cases (24.1%) at a rate of 10.34 per 100 patient-years. At 5 years, the freedom from reintervention for elective cases was 62.6%. Freedom from ACM and ARM was 57.6% and 85.6% at 5 years.

Of the surviving 189 patients, 13 have been discharged from follow-up, because of increasing physical frailty and the difficulty faced in travelling for appointments. Decisions were taken with the patients, following face-to-face discussion. Of these 13 patients, 6 have features of therapeutic failure and a bilateral decision has been taken not to attempt further reintervention.

**Infrarenal EVAS**

EVAS was performed for 185 intact infrarenal aneurysms; 160 elective and 25 non-elective. Non-elective cases were for symptomatic or ruptured aneurysms (which are discussed separately). Thirty-day mortality was 0.54% and represents a single patient who died on postoperative day 19, following discharge from hospital.

Median follow-up was 2.67 years (IQR 1.54-3.84 years). Therapeutic failure occurred in 73/185 cases (39.5%), at a rate of 14.83 per 100 patient-years. Freedom from therapeutic failure at 2.67 and 5 years was 77.77% and 30.64% respectively. Eleven secondary ruptures occurred (5.9%) at a rate of 2.44 per 100 patient-years. Ruptures occurred at a median of 2.42 years post procedure, and only one occurred within a year of the index procedure. Kaplan-Meier survival estimates of freedom from complications are shown in table 2.

Freedom from reintervention was 80.5% and 52.3% at 2.67 and 5 years. Freedom from ACM and ARM was 79.2% and 58.1%, and 95.6% and 87.0% at 2.67 and 5 years.

Over 80% of aneurysms fell outside the IFUs for conventional bifurcated EVAR devices. Morphology in 91/185 cases (49.2%) fell within the original (2013) Nellix IFU, whereas only 34/185 (18.4%) aneurysms fell within the revised (2016) Nellix IFU. Compliance with the 2016 IFU did not appear to reduce complications or therapeutic failure rates (Table 2). Conversely, those outside the 2013 IFU fared less well in follow-up than those within. This was seen most noticeably in the formation of type 1a endoleaks (p=0.010), ACM (p=0.007) and ARM (p=0.006). There were no significant differences seen in secondary rupture, therapeutic failure or reinterventions.

Therapeutic failure was more common 2 years or more after implantation (Figure 1). Secondary rupture appeared to be effectively prevented by timely reintervention when signs of therapeutic failure were detected. Fifteen of the 19 cases of graft migration were subsequently treated with NINA.

**Chimney EVAS**

ChEVAS was undertaken in 79 cases; 73 treated intact juxta- and suprarenal aneurysms and 6 treated ruptured aneurysms (Table 3). In 23 cases the aneurysms were considered unsuitable for a custom-made device by the multi-disciplinary team and in 22, the aneurysm required urgent treatment. Twenty-two cases were revisions of previous aneurysm repairs (10 EVAR, 9 EVAS and 3 open repairs). Thirty-three cases employed a single chimney, 26 cases two chimneys and 20 three chimneys. Target vessel patency is 98.5%.

The 30-day mortality rate for ChEVAS for an intact aneurysm was 4.11% (3/73 cases). One was due to mesenteric ischaemia, one to renal haemorrhage and a third to multiple organ failure following endobag rupture and polymer leak.

Two secondary ruptures occurred following ChEVAS (5.9%), both two years postoperatively, at a rate of 1.36 per 100 patient-years. Freedom from secondary rupture was 97.6% and 91.2% at 2 and 4 years respectively. Freedom from ACM was 81.5% and 73.1% at 2 and 4 years (p=0.533, Figure 2) and freedom from ARM was 90.9% and 86.8% at 2 and 4 years. ACM was significantly greater in patients treated non-electively (P=0.017) (Figure 3). There was a trend towards higher secondary aneurysm rupture rates in those patients treated with more chimneys (freedom from secondary rupture at 4 years 100% 1 chimney, 94.7% 2 chimneys, and 83.3% 3 chimneys; p=0.093).

The difference in mortality between elective and non-elective cases occurred in the post-operative period, after which the survival trajectory was the same. Table 3 shows survival estimates for freedom without complications according to the number of chimneys deployed.

Therapeutic failure occurred in 19 cases (24.1%) at a rate of 12.88 per 100 patient-years. Reintervention was undertaken in 13 cases (16.5%), or 8.81 per 100 patient-years. The number of chimney grafts did not have a statistically significant impact on any of the postoperative complications.

There were no significant differences observed either way in the outcomes between EVAS and Ch-EVAS (Figure 4). Therapeutic failure, and subsets of this composite measure, followed almost identical trajectories, as did those for reinterventions and all-cause mortality.

**Nellix-in -Nellix (NINA)**

NINA was used for reinterventions, with or without chimney grafts, to re-establish a proximal seal after caudal migration of Nellix stentgrafts and/or the formation of type 1a endoleak. Fifteen cases were undertaken, 6 NINA and 9 ChNINA.

30-day mortality was 13.3%. There were 3/15 (20.0%) recurrent type 1a endoleaks, 2 undergoing further embolisation. Recurrent type 1a endoleak in the ChNINA group was associated with further stent migration and sac expansion. There was one secondary rupture in the NINA/ChNINA group.

Median follow-up was 0.42 years (IQR 0.16-0.83 years). Freedom from therapeutic failure at 0.42 and 1.5 years was 85.7% and 57.1%. Freedom from ACM and ARM at 0.42 and 1.5 years was 93.3% and 84.8%, and 93.3% and 93.3%.

**Iliac aneurysms**

Thirteen common iliac artery aneurysms were treated, with no deaths within 30 days and 1 (7.69%) within a year. There was 1/13 (7.69%) therapeutic failure, and 2 type 2 endoleaks arising from the internal iliac artery, none requiring reintervention. Type 1a endoleak in this cohort was seen in a single case where dilatation of a previously normal calibre abdominal aorta, was associated with device migration at the level of the renal arteries. As this procedure had been undertaken to treat a common iliac aneurysm, which had decreased in size, reintervention was not deemed necessary.

Median follow-up was 2.38 years (IQR 1.01-3.63 years). Freedom from therapeutic failure at 2.38 and 4 years is 100% and 85.7%. Freedom from ACM at median follow-up and 4 years was 85.7% and 70.1%. There were no aneurysm-related mortalities.

**Primary treatment of ruptured AAA**

EVAS was used in 18 cases of aortic rupture, with 6/18 (33.3%) cases with adjunctive chimney grafts to create a landing zone. 30-day mortality was 33.33%. Two patients underwent reintervention; 1 explantation of the Nellix stentgrafts on postoperative day 2 for a secondary rupture; the patient remains alive at 3.5 years. The second involved distal extension of the stentgraft to treat a type 1b endoleak; she survived a further year before dying of renal failure, which predated her initial AAA rupture.

Median follow-up was 0.27 years (IQR 0.03-2.46 years). Freedom from therapeutic failure was 85.2% at both 0.27 and 4 years. Freedom from ACM and ARM at 0.27 and 4 years was 82.4% and 23.5%, and 82.4% and 64.7%.

**Discussion**

This study represents a large number of patients treated with a novel device in a single institution, as well as one of the earliest global series. New medical technologies are unavoidably associated with new complications that require both definition and appropriate management strategies. As such, during the study period, the procedural technical aspects for deployment evolved or were refined. The Nellix device itself underwent iteration during this timeframe to improve the delivery system and to fix the endobag to the stent distally, addressing an issue of type 1b endoleaks. Local and global experience has given us a better understanding of which aneurysms should be treated with the Nellix device and which application would work best.

The greatest challenge to successful EVAR has been hostile neck anatomy. Previous studies demonstrated that adverse neck anatomy was associated with poorer outcomes and a greater need for reintervention(26-28). One of the perceived advantages of EVAS was that it may significantly reduce the incidence of all endoleaks and thus future need for reintervention. It was hoped that active management of the aneurysm sac may eliminate type 2 endoleaks in particular. Nellix appeared to have the potential to treat a wider range of aneurysm morphologies and avoided the requirement for proximal fixation. The polymer sealing technology was reported to be able to create a seal in short, conical and angulated necks that were high risk for EVAR(13).

Early results were promising with low rates of ARM, endoleak and a lower burden of post-implantation syndrome (PIS). As experience increased and a worldwide community of users shared learning, increasingly complex aneurysms were treated, often in patients for whom there was no other endovascular option and for whom open repair presented a prohibitive operative risk.

This early success does not appear to have translated into equally promising published mid-term results(25). In the Cambridge series, and this series, in a significant proportion of cases, and in some subgroups exceeding 50% at 4 years, therapeutic failure was observed. This presented as sac expansion with or without endoleak, graft migration, or type 1a/b endoleak. In some cases, patients presented with secondary aneurysm rupture, which in a small number of cases proved fatal. In some of these cases imaging in the days prior to rupture had not revealed any complication.

The rate of secondary aneurysm rupture in this study is higher than reported for EVAR devices. The rupture rate for EVAS treating elective and non-elective intact, infrarenal AAA was 2.44 per 100 patient-years, and 1.87 ruptures per 100 patient-years for elective cases. This figure mirrors that reported in the Cambridge EVAS series of 2.4 ruptures per 100 patient-years (25). By comparison, a late secondary rupture rate of 0.6 per 100 patient-years was reported in the UK EVAR trials(29). On this basis it would appear that EVAS is less effective at preventing aortic rupture than EVAR, although the authors believe that the morphologies are unlikely to be comparable between studies, which would affect the expected complication rates. The results from Cambridge and those presented here open a debate as to whether EVAS is equally as effective at preventing aneurysm rupture in follow-up as other treatment methods, including EVAR and open aneurysm repair.

A significant burden of type 1b endoleaks was seen and significantly associated with sac expansion. This was almost certainly due to the short graft lengths available in the early iteration of the Nellix device and the fact that the endobag was not fixed to the stent distally. These may have meant that the sealing in the common iliac artery at the primary procedure was insufficient, potentially leading to endoleak in follow-up. Whether there is a conceptual debate to be had regarding the role of vessel sealing with polymer as opposed to more traditional sealing stents is unclear, but a high rate of type 1b endoleaks was observed in this series.

The incidence of type 2 endoleaks was low, at 3.4% across the entire cohort. This compared well with 16.8% and 14.6% at midterm follow-up using older (pre-2004) and newer EVAR stent grafts in a study of 1412 patients(30). It would appear that the concept of sac filling could be of benefit in preventing type 2 endoleaks, and in the authors’ opinion this remains a significant target for technological advancement in endovascular therapies for aneurysm care.

Delineating known complications in the setting of a novel device presents challenges, in particular detecting type 1a endoleak. Endoleaks with EVAS are potentially more difficult to detect intraoperatively and immediately postoperatively in particular if contrast has been used in the filling of the endobags. They may become clearer beyond three months postoperatively in follow-up as the appearance of the endobag changes. The location of endoleaks is different from that seen with bifurcated EVAR devices, for example, contrast enhancement may be seen at the peripheries of the aneurysm sac (between the endobag and the sac), or in the cleft in between the endobags, and may precede stent separation (31-33). Once detected there is the issue of how to treat them. The 2-stent configuration of the Nellix system limits the options in terms of reinterventions, precluding the use of fenestrated of conventional aortic cuff devices. Options include endoleak embolisation, NINA, ChNINA or graft explantation.

Reinterventions for neck-related complications were managed through a range of strategies, selected on the basis of the morphology and patient fitness. In some cases graft explantation was undertaken. This is now the primary mode of managing therapeutic failure in our unit in a patient deemed physiologically fit. This is subsequent to the observed further migration and type 1a endoleak rate following a NINA strategy in this series. There appears to be a more robust solution using ChNINA, but this is a very significant revisional procedure and is reserved for those unfit for graft explantation in our unit. Other patients underwent embolisation, but we have observed recurrent endoleak, with a third of patients in this cohort requiring repeat embolisation.

Off-label applications of the EVAS device with chimneys and for iliac aneurysms have performed no worse than the intended infrarenal use, suggesting it may still represent a therapeutic option for selected more complex aortic morphologies. Therapeutic failure was observed at a lower rate in both the ChEVAS and iliac use at 12.88 and 0.31 failures per 100 patient-years as compared with 14.22 for the infrarenal cohort. The rates of secondary aortic rupture were also lower with these applications at 1.36 and 0 ruptures per 100 patient years for the ChEVAS and iliac groups respectively, compared with 2.44 for the infrarenal cohort. It is recognised however, that the most serious complications have largely occurred after 2 years and the follow-up for these off-label applications lags behind that for the infrarenal treatments. It is possible therefore that these have simply not yet been observed, and longer follow-up is required.

Compliance with the revised (2016) IFU did not show any statistically significant difference in terms of incidence of any of the complications described in this series. This would suggest that the rate of therapeutic failure seen in this study is not simply due to the fact that many of the aneurysms treated had complex anatomy. It is important to bear in mind that the number of patients treated within the revised IFU was small (18.4%) as the majority of infrarenal cases were undertaken prior to the IFU revision. This observation reflects that reported in another large series by Zerwes et al(19). Compliance with the original (2013) IFU did show significantly lower incidence of type 1a endoleak and aneurysm-related and all-cause mortality.

**Strengths and Limitations**

This is the largest EVAS study to be reported worldwide from a single institution. This report is based on having recalled all patients for combined CT, duplex and clinical follow-up to provide the most accurate assessment of outcomes. The report is therefore objective in the assessment of this novel, disruptive technology.

As a single-centre study, we cannot be sure how our results will compare with those from other centres, however there does seem to be concordance with other midterm results. These data represent our complete experience with this device and therefore document the learning curve and technique evolution, as well as refinement in our detection and treatment of complications. Although this study reports on consecutive patients undergoing EVAS treatment, other endovascular devices were being used at our institution during this period, and there is the possibility that selection bias may exist, which would be impossible to quantify.

The mid-term results with this device raise important questions within the vascular community regarding the adoption and enthusiasm for novel technologies. Innovation is vital to improve the treatments vascular surgeons can deliver. However, innovation should not take precedence over robust safety and efficacy data. The 30-day and 1-year outcomes for the Nellix device were very encouraging, and safety in the short term appeared to be established. However, many centres with the largest series are now reporting high rates of graft failure at 2 years and beyond. The CE mark has been suspended following a voluntary recall of the device by Endologix. This is the first device to use polymer sac sealing technology and the premise of completely filling the aneurysm sac does appear to associated with a significantly lower incidence of post-implantation syndrome when compared with EVAR (34).

**Conclusion**

This study reports on the use of a novel endovascular treatment for abdominal aortic aneurysm. It represents a heterogeneous range of aortic morphologies and pathologies. The early results were satisfactory, but high rates of therapeutic failure and secondary rupture were seen beyond 2 years of follow-up. Robust, device-specific imaging surveillance and clinical follow-up for novel technologies appears essential to detect idiosyncratic modes of failure, in order to reintervene and to prevent life-threatening complications such as secondary aneurysm rupture.

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