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Trends in Thoracic Aortic Aneurysm Hospital Admissions, Interventions, and Mortality in England between 1998 and 2020: An Observational Study

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WHAT THIS PAPER ADDS

This observational study spanning a 23 year period revealed that there has been a significant increase in hospital admissions for thoracic aortic aneurysms in the UK, with a parallel increase in thoracic endovascular aortic repair (TEVAR) uptake and a decline in aneurysm related mortality. In the absence of randomised trial data, the trends observed in this 'real world' dataset, and the significant reduction in aneurysm related mortality in the endovascular era *vs.* the pre-endovascular era, support the clinical efficacy of TEVAR and provide some evidence for its continued use.

Objective: To assess trends in thoracic aortic aneurysm (TAA) hospital admissions, interventions, and aneurysm related mortality (ARM) in England, and examine the impact of endovascular repair on mortality for the years 1998 to 2020.
Methods: Hospital admission and operative approach (thoracic endovascular aortic repair, [TEVAR] or open surgical repair) using Hospital Episodes Statistics, and ARM data from the Office for National Statistics for England standardised to the 2013 European Standard Population were analysed using linear regression and Joinpoint regression analyses. ARM was compared between the pre-endovascular era (1998 — 2008) and the endovascular era (2009 — 2019).
Results: A rising trend in hospital admission incidence has been observed, mainly due non-ruptured admissions (4.11 per 100 000 in 1998; 95% confidence interval (CI) 3.71 — 4.50 to 12.61 per 100 000 in 2020; 95% CI 12.00 — 13.21 in 2020; $r^2 = .98$; $p < .001$). Operative interventions increased mainly due to an increase in TEVAR (2.15 per 100 000; 95% CI 1.91 — 2.41 in 2020 *vs.* 0.26 per 100 000; 95% CI 0.16 — 0.36 in 2006; $r^2 = .90$; $p < .001$). Reductions in ARM from TAA were observed for males and females, irrespective of age and rupture status. The greatest reduction in ARM in the endovascular era was observed in females aged $>$ 80 years with ruptured disease (15.26 deaths per 100 000 *vs.* 9.50 deaths per 100 000; $p < .001$).
Conclusion: A significant increase in hospital admissions for non-ruptured TAA has been observed in the last 23 years in England, paralleled by a shift towards endovascular repair, and significant declining trends in ARM, irrespective of sex and age. The significant reductions in age standardised death rates from ruptured and non-ruptured TAA in the endovascular era, particularly for females aged $>$ 80 years with ruptured disease, affirm the positive impact of an endovascular approach to TAA.

Keywords: Mortality, Thoracic aneurysms, Thoracic endovascular aortic repair
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INTRODUCTION

Aortic aneurysmal disease is a significant public health concern given a natural history of continued aortic expansion and eventual rupture, an event that is fatal in 80% of people.[1] During the twentieth century, a steady increase in aortic aneurysm mortality was reported.[2] However, several population based studies have demonstrated a decline in both abdominal and thoracic aortic aneurysm (TAA) deaths during the twenty first century.[3–5] This trend was hypothesised to be the result of public health measures targeting cardiovascular risk factors associated with aortic rupture, such as smoking and hypertension, rather than the improved trends in operative mortality from aortic repair, and particularly the increased implementation of minimally invasive thoracic endovascular aortic repair (TEVAR) that was embraced in the 2000s.[5]

TEVAR has become firmly established in contemporary vascular practice, supplanting traditional open surgical repair (OSR), and is recommended as a treatment strategy in both the European[6] and US[7] vascular societies' practice guidelines. Furthermore, the adoption of endovascular technology shows no sign of slowing down, with the ongoing evolution of new and expensive devices to treat disease in the aortic arch, in the absence of randomised trial data.[8]

The conclusions of prior population based studies may now be outdated and reflect outcomes related to clinical practice at the time; the analysed data in many of these studies was from early time periods when TEVAR technology and practice were immature, and during the development of a learning curve with respect to endovascular skill and patient selection. The primary aim of this study was to undertake a recent analysis of the trends of hospital admissions, operative approach, and aneurysm related mortality (ARM) for TAA for unselected "real world" patients in England, and to examine the potential impact of endovascular repair on mortality.

MATERIALS AND METHODS

Study design and participants

This population based cohort study included a retrospective review of the following outcome data for all patients older than 60 years in England who (1) had a hospital admission for a diagnosis of ruptured or non-ruptured TAA (admission data); (2) underwent OSR or TEVAR for TAA (procedural data); and (3) were registered on death certificates to have died from TAA (in or out of hospital ARM data).

Data sources

Hospital admission (based on International Classification of Diseases [ICD] version 9 and 10 codes) and procedural data (according to the Office of Population, Censuses and Surveys: classification of interventions and procedures, 4th revision [OPCS-4]) were obtained from Hospital Episodes Statistics (HES), an administrative data warehouse that is publicly and freely available through the National Health Service (NHS) Digital platform.[9] HES contains details of the activity of hospitals within the NHS in England, including all admissions, diagnoses, and treatment procedures. Individual patient level data or hospital identifiers were not available to the researchers. Mortality data were obtained from the Office for National Statistics for England (ONS), which collates cause of death from death certificates (data requested 2 November 2020, reference number 12426).[10] The authors did not have access to the proportion of patients who underwent autopsy to confirm the diagnosis. Both HES and ONS data sources have been used in similar studies and are well validated administrative databases.[11,12] The full list of ICD-9/10 and OPCS codes used are provided in Supplementary Figure S1.

Inclusion and exclusion criteria

Owing to the broad age bands provided in the HES dataset (18 − 59 years) for certain calendar years, and to ensure the inclusion of degenerative aneurysms only (as opposed to post-dissection aneurysms in individuals with connective tissue pathologies), all data extraction was restricted to patients older than 60 years and in five year age bands. Patients who underwent repair of aneurysmal disease of the ascending aorta, aneurysmal aortic surgery where the segment of aorta was not specified ("other specified or unspecified aneurysmal aorta"), "revision" surgery, aortic surgery without the mention of "aneurysm" (likely related to occlusive disease), for both open and endovascular repair, were excluded to increase the sensitivity of the data towards the specified thoracic aortic segment, and aneurysmal pathology rather than steno-occlusive pathology.

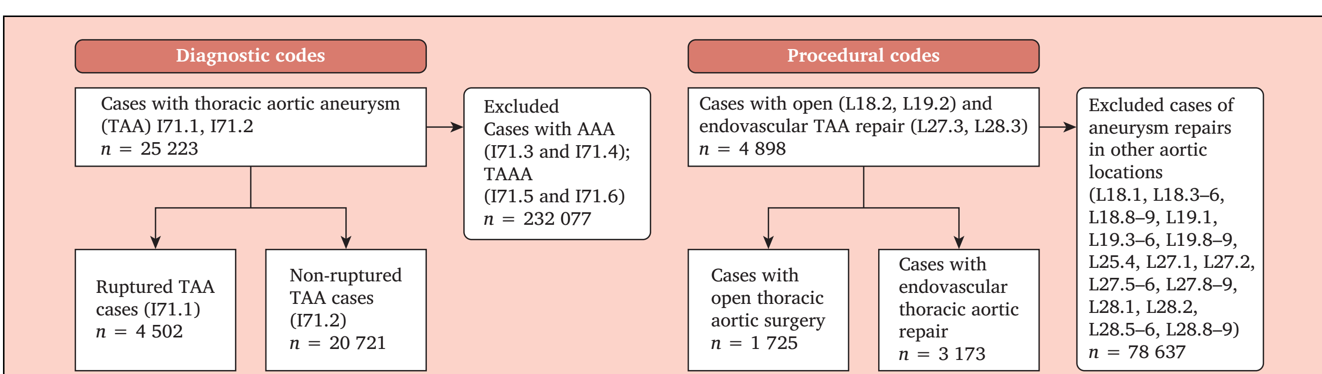

Figure 1. Patient flow chart to assess trends in thoracic aortic aneurysm (TAA) hospital admissions, interventions, and aneurysm related mortality in England for the years 1998 to 2020. AAA = abdominal aortic aneurysm; TAAA = thoraco-abdominal aortic aneurysm.

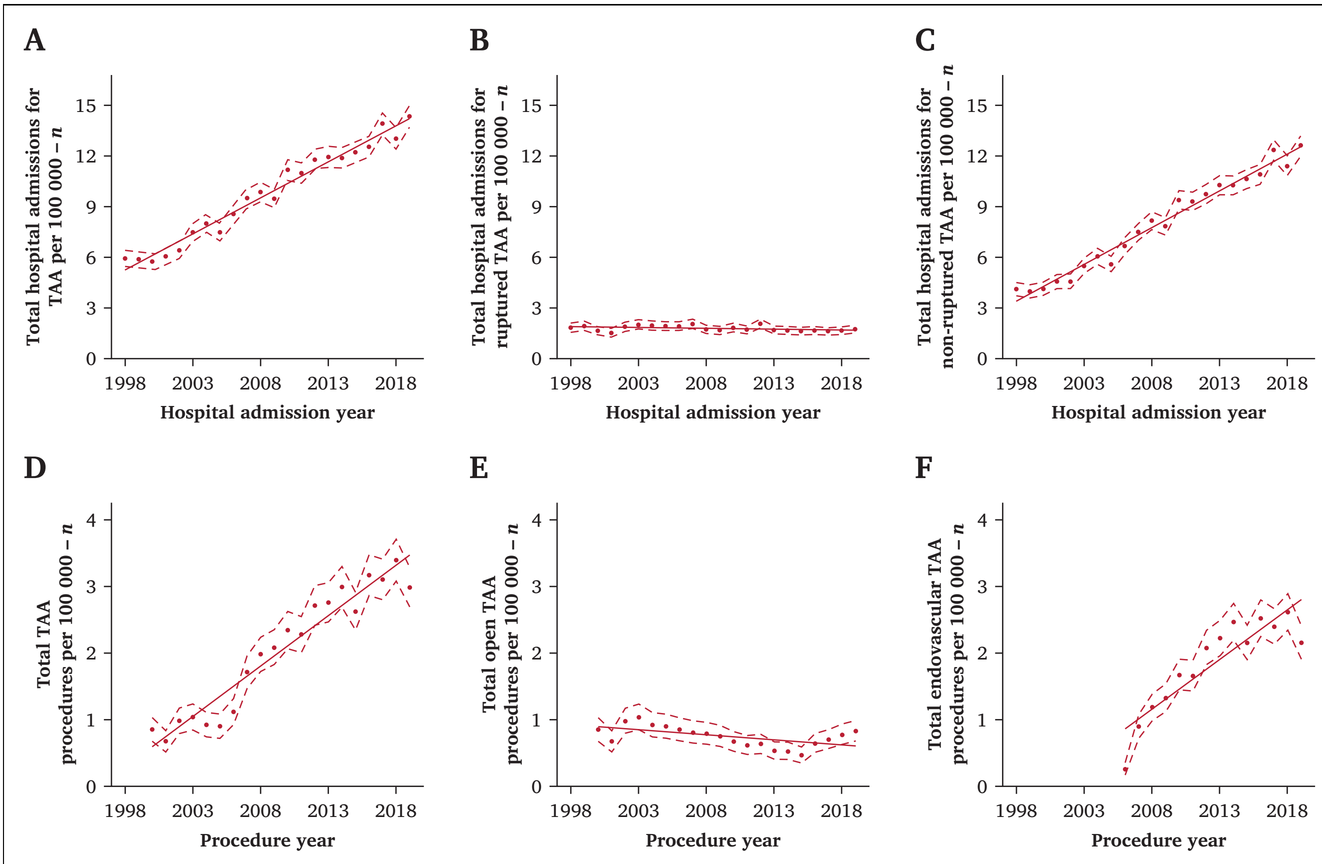

Figure 2. Trends in total hospital admissions for (A) thoracic aortic aneurysms (TAA), (B) ruptured TAA, and (C) non-ruptured TAA; and (D) total procedures, (E) total open procedures, and (F) total endovascular procedures for TAA in England between 1998 and 2020.

Data handling

The patient flow chart is depicted in Figure 1. The number of admissions (according to rupture status), the number of OSRs and endovascular procedures, and the number of deaths for ruptured and non-ruptured TAAs were collated for each year. Admission data for TAA are presented for 1 April 1998 to 31 March 2020. HES procedural data for TAA are presented for 1 April 2000 to 31 March 2020 because of difficulty in obtaining procedural and mortality data prior to 2000. Both admission and procedural data are presented as crude admission and procedure rates, defined as the number of admissions and procedures per number of patients aged 60 years or older living for a given year, respectively. Admission and procedural data according to five year age bands were not available. Sex specific age standardised death rates (ASDRs) are presented for the period 1 April 1998 to 31 March 2019, as 2020 data had not yet been released at the time of writing. ASDRs were calculated using the 2013 European Standard Population over the age of 60 years and stratified into 60 – 79 years and > 80 years for males and females, and for ruptured and non-ruptured disease, respectively (see Supplementary Text S1).

Statistical analysis

Trends in admissions and procedures were assessed with linear regression using SPSS version 27 (IBM, Armonk, NY, USA). ASDR trends were assessed using Joinpoint regression modelling (Joinpoint Command Line Version 4.5.0.1) provided by the US National Cancer Institute Surveillance Research Program according to the authors' previous methodology (see Supplementary Text S2).[3] Estimated annual percentage change (EAPC) for each significant change in trend with its confidence intervals (CIs) were calculated. To examine the impact of endovascular repair on ASDR, the Mann–Whitney test was used to test the statistical significance of ASDR between the pre-endovascular era (1998 – 2008) and the endovascular era (2009 – 2019). This cutoff was chosen as TEVAR superseded OSR in 2008. An alpha level of < .05 was considered to be statistically significant for all analyses.

RESULTS

Hospital admission trends

The in hospital incidence for total admissions ranged between 5.95 per 100 000 in 1998 (95% CI 5.47 – 6.42) to 14.36 per 100 000 in 2020 (95% CI 13.71 – 15.00), with a mean increase of 6.4% per annum (linear regression $r^2 = .97$; $p < .001$). The in hospital incidence for non-ruptured admissions ranged from 4.11 per 100 000 in 1998 (95% CI 3.71 – 4.50) to 12.61 per 100 000 in 2020 (95% CI 12.00 – 13.21) in 2020, with a mean increase of 9.3% per annum ($r^2 = .98$; $p < .001$). Ruptured TAA admissions appeared

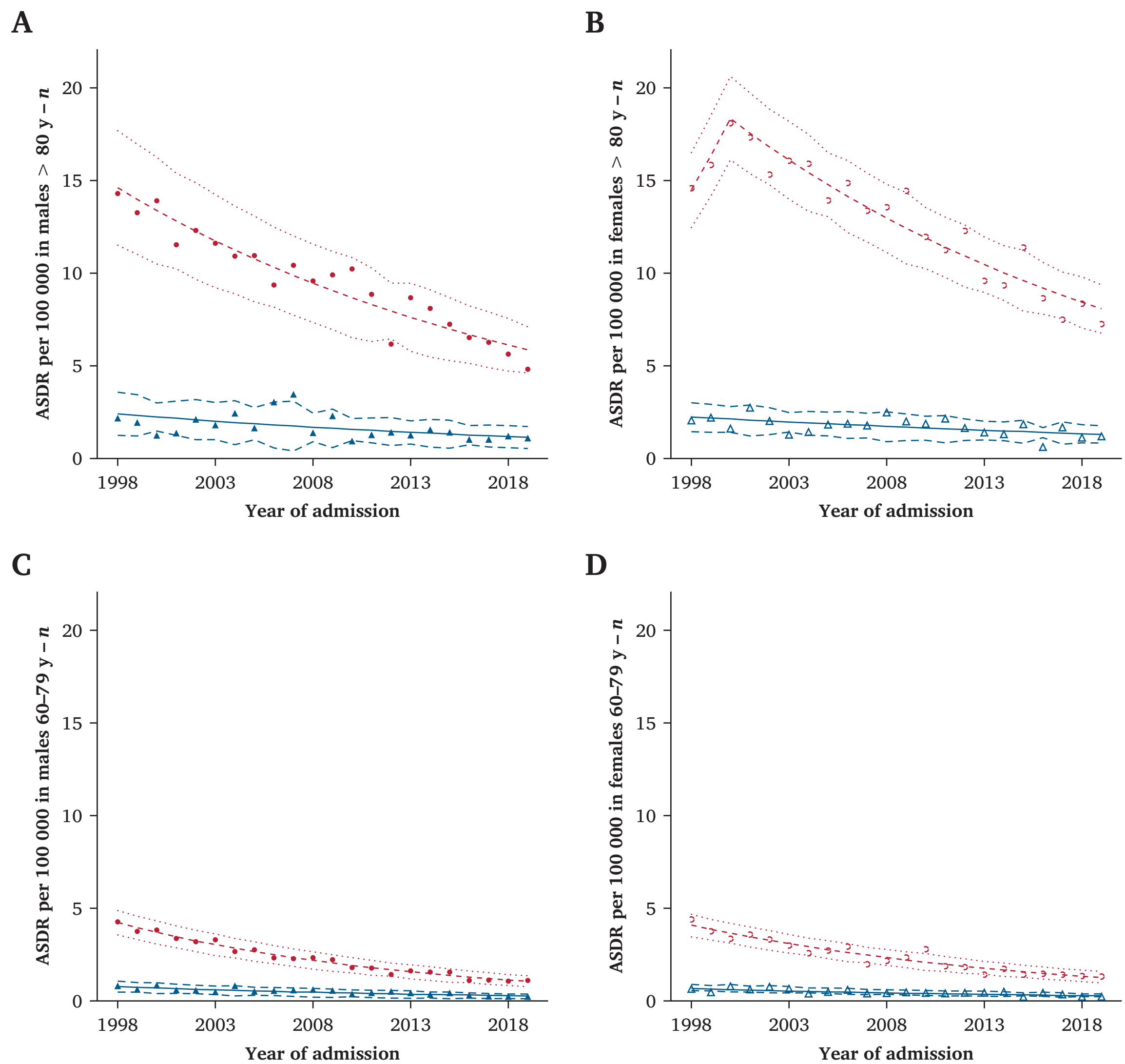

Figure 3. Trends in age and sex standardised mortality for ruptured (circle) and non-ruptured (triangle) thoracic aortic aneurysms (TAA) in (A) men and (B) women > 80 years of age, and in (C) men and (D) women aged 60 – 79 years in England between 1998 and 2020. ASDR = age standardised death rate.

relatively unchanged over the 22 year period ($r^2 = .10$; $p = .082$, Fig. 2A).

Operative intervention trends

A total of 0.85 per 100 000 (95% CI 0.67 – 1.03) procedures were carried out on TAAs in 1998 and 2.99 per 100 000 in 2020 (95% CI 2.60 – 3.28), with a mean increase of 11.3% per annum ($r^2 = .93$; $p < .001$). The increasing trend in operative interventions was paralleled by an increasing trend in TEVAR procedures ($r^2 = .90$; $p < .001$), whereby 2.15 per 100 000 TEVARs (95% CI 1.91 – 2.41) were carried out in 2020 *vs.* 0.26 per 100 000 procedures (95% CI 0.16 – 0.36) in 2006. Conversely, OSR appears to have declined over the last 23 years ($r^2 = .29$, $p = .008$).

Mortality trends

Figure 3 shows the results of the Joinpoint regression analysis for trends in mortality in males and females aged 60 – 79 years and > 80 years for ruptured and non-ruptured TAA, respectively. The ASDR per 100 000 for each year were proportionally higher for ruptured disease irrespective of sex and age, with the highest ASDR for each year observed in women over the age of 80 years with ruptured disease. Very little difference was observed for ASDR for each year between men and women aged 60 – 79 years for ruptured and non-ruptured disease.

A consistent declining trend in aneurysm related ASDRs from TAAs was observed over the studied 23 years for both ruptured and non-ruptured disease, irrespective of sex and age. The EAPCs, shown in Table 1, demonstrate statistically significant reductions in ASDRs from TAA in all groups. In men, the largest single trend of decreasing EAPCs was observed in those aged 60 – 79 years with ruptured disease (EAPC −6.30, 95% CI −5.90 – −6.80), whereas in females this was seen in those aged 60 – 79 years with non-ruptured disease (EAPC −4.40, 95% CI −2.70 – −6.10) and those

Table 1. Joinpoint regression analysis for mortality from ruptured and non-ruptured thoracic aortic aneurysms for those aged > 60 years in England from 1998 to 2019 for aneurysm related age standardised death rate

	Age − y	Trend 1		Trend 2	
		Years	EAPC	Years	EAPC
Ruptured aneurysms					
Male	60–79	1998–2019	−6.30* (−5.90 − −6.80)		
Male	>80	1998–2019	−4.20* (−3.60 − −4.90)		
Female	60–79	1998–2019	−5.4* (−4.70 − −6.10)		
Female	>80	1998–2000	12.90 (−12.10 − 44.90)	2000–2019	−4.20* (−3.50 − −5.80)
Non-ruptured aneurysms					
Male	60–79	1998–2019	−5.10* (−3.60 − −5.10)		
Male	>80	1998–2019	−3.50* (−1.00 − −5.90)		
Female	60–79	1998–2019	−4.40* (−2.70 − −6.10)		
Female	>80	1998–2019	−2.60* (−0.70 − −4.40)		

EAPC = estimated annual percentage change.
* Statistically significant ($p < .05$).

aged > 80 years (EAPC −4.20, 95% CI −3.50 − −5.80). A significant reduction in aneurysm related ASDR from ruptured and non-ruptured TAAs was observed for all subgroups comparing the 1998 − 2008 and 2009 − 2019 time periods, except for women over the age of 80 years with non-ruptured disease ($p = .068$; Fig. 4). Women over the age of 80 years with ruptured disease exhibited the greatest reduction in ASDR in the endovascular era (15.26 deaths per 100 000 *vs.* 9.50 deaths per 100 000; $p < .001$).

DISCUSSION

This population based cohort study examined “real world” trends in hospital admissions, operative intervention, and ARM from TAA in England over the last 23 years. The main study findings included a significant increase in hospital admissions for non-ruptured TAAs, accompanied by an increase in operative intervention, specifically a significant rise in the use of TEVAR, and an overall decrease in ARM for ruptured and non-ruptured disease, regardless of sex and age group.

Earlier interrogation of the English HES database (between 1999 and 2010) observed the decline in ARM to occur as early as 1999, well before the widespread implementation of TEVAR.[5] The authors attributed this to improved risk factor management, such as smoking cessation, blood pressure control, and increased prescription of statins, in line with the declining trends in mortality from other cardiovascular diseases.[13]

While the prevalence of smoking in England fell substantially in the late 1970s and early 1980s (45% in 1974 to 35% in 1982) with the introduction of antismoking campaigns launched by the Health Education Council in England and Wales in the late 1960s, and other smoking cessation agreements between the tobacco industry and the government,[14] the rate of smoking decline has, in fact, slowed in the last 10 years.[15] Similarly, while the late 1990s to early 2000s saw a rise in statin initiation therapy for the primary prevention of cardiovascular disease in the UK, this was followed by a decline up to 2011, with rates remaining constant thereafter.[16] Furthermore, while awareness and treatment of hypertension have increased over time, much of the improvement occurred before the mid-2000s with awareness, treatment, and blood pressure control plateauing since then.[17] Improved risk factor management cannot wholly explain the ongoing decline in the TAA mortality rate.

Further analysis of the HES database over the 23 years of this study suggests that improved case ascertainment, the increased uptake of prophylactic repair of intact (non-ruptured) TAAs, and, specifically, the preferential use of TEVAR may provide additional plausible explanations for the declining ARM rate. This is substantiated by the increased number of admissions for non-ruptured TAAs that has mirrored the sharp rise in TEVAR, alongside declining trends in ruptured (as well as non-ruptured) ARM.

Improved case ascertainment is probably the result of advances and the widespread availability of sensitive cross sectional imaging introduced in the 1970s and early 1980s. Similar rising trends in hospital admissions for TAA have been observed in other contemporary studies from Germany,[18] Canada,[19] and the USA.[20] Improved case ascertainment is likely to have contributed to the prevention of premature rupture related deaths through early identification, monitoring of aortic growth rate through regular surveillance, and prophylactic repair of non-ruptured aneurysms when treatment indication predicated on aortic diameter is met.[21] While there is no screening programme for TAA in the UK (or in other countries), the UK NHS Abdominal Aortic Aneurysms Screening Programme (NAAASP, implemented in 2009) may represent another pathway for the increased detection of synchronous or metachronous TAAs; 19.2% of patients with abdominal aortic aneurysm are known to have TAAs, permitting the (incidental) detection of TAAs upon referral to a vascular service for a “screen detected” abdominal aortic aneurysm.[22] The decline in ARM is perhaps less likely to be related to a decline in ruptured disease incidence due to risk factor management given that admission numbers for ruptured TAAs have been steady for the last 23 years.

The declining ARM for both ruptured and non-ruptured disease in this observational analysis parallels the

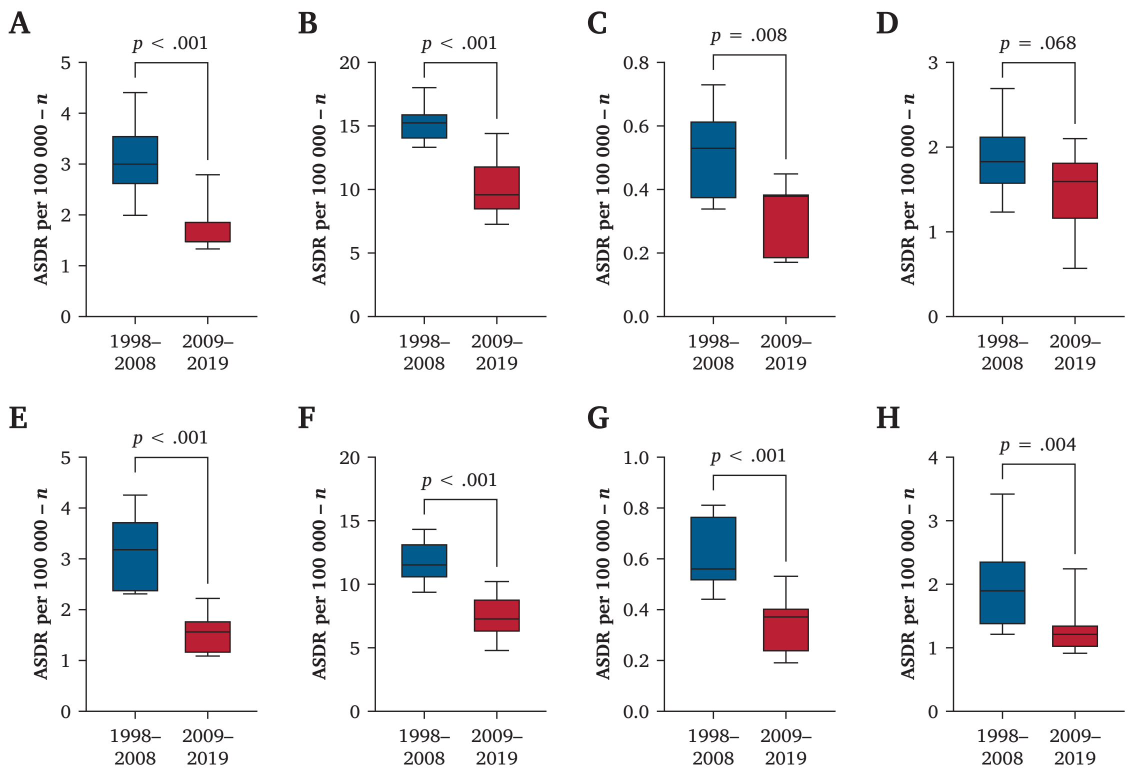

Figure 4. Changes in age standardised death rates (ASDR) per 100 000 population for women with ruptured thoracic aortic aneurysms (TAA) aged (A) 60 – 79 years and (B) > 80 years, for women with unruptured TAA aged (C) 60 – 79 years and (D) > 80 years, in men with ruptured TAA aged (E) 60 – 79 years and (F) > 80 years, and in men with unruptured TAA aged (G) 60 – 79 years and (H) > 80 years. Mann–Whitney test used to assess for statistical significance.

supplantation of OSR by TEVAR. This finding, together with the significant reductions in ARM in the endovascular era compared with the pre-endovascular era, highlight the influence of minimally invasive endovascular repair in preventing deaths from TAA rupture. The management of TAAs has seen significant changes in past decades, with a shift away from OSR to TEVAR in the UK and globally. A study of 9 518 TEVARs for the treatment of thoracic aortic disease based on VASCUNET, an international vascular registry collaboration of 13 countries, reported that TEVAR has become the primary surgical treatment modality for descending aortic pathologies, with TEVAR constituting between 40% and 72% of TAA repairs in the USA (40%), New Zealand, Sweden, France, Spain, Switzerland, Australia, Italy, Finland, Germany, Serbia, Hungary, and the UK (72%).[23] This is unsurprising given that OSR remains a high risk procedure, even in experienced high volume centres.[24] While there have been no randomised trials to support the use of TEVAR over OSR, the EVAR trials have provided an indirect evidence base,[25,26] with single centre,[27] industry sponsored registries,[28,29] and population based studies[30–33] all confirming the lower complication rate and early survival advantage of TEVAR *vs.* OSR.

While the significantly improved peri-operative mortality of TEVAR has led to increasing adoption of this treatment modality, the longer term outcomes remain less clear, with uncertainty regarding the effectiveness of TEVAR on mid to long term mortality and survival on a population basis. This was driven, in part, by long term data from the EVAR trials, which demonstrated an increased risk of ARM after eight years owing to concerns regarding the durability of the stent graft technology (increased secondary/late intervention and aneurysm rupture with EVAR *vs.* OSR).[34] Similarly, early analysis of the English HES data (2006 – 2011)[35] and Medicare data (2004 – 2007)[36] both demonstrated significantly worse survival with TEVAR compared with OSR at five years. However, this was mainly due to cardiopulmonary events rather than aortic related mortality, re-affirming the paramount importance of patient selection.

ARM in this dataset represents both in and out of hospital deaths and therefore encompasses peri-operative mortality, as well as long term mortality, irrespective of whether the patient underwent re-intervention. While this dataset does not permit identification of re-interventions, the declining trends in ASDR from ruptured and non-ruptured TAA over the last 23 years, and the significant reductions in ASDR between the pre-endovascular era and the endovascular era, provide further support for the clinical efficacy of TEVAR. Similar findings were also observed on further interrogation of the Medicare database (1999 – 2010) with longer follow up whereby TEVAR was associated with a greater mean patient survival than OSR up to nine years, leading the authors to support TEVAR as the first line treatment for thoracic aortic aneurysms.[30]

An interesting observation from the present study is the decline in ARM from TAA for two high risk groups; people over the age of 80 years, and in women, with the greatest rate of decline observed in ruptured disease, which parallels the increased use of TEVAR. While TEVAR has increased the overall pool of patients eligible for operative intervention who, in the past, may have been turned down for OSR due to their advanced age and comorbidities, the benefit of TEVAR in octogenarians remains a subject of debate, especially in acute settings, owing to their frail physiology and limited life expectancy.[37−39] Female sex has also been associated with poorer surgical outcomes.[40] This is likely to be multifactorial and, in part, due to the higher age (and therefore greater comorbidities) of women at diagnosis and intervention, and due to the anatomical differences (smaller diameter access vessels) between men and women that make endovascular repair more technically challenging in women.[41−43] Nevertheless, these findings provide further support for the use of endovascular technology in the treatment of TAA. The proportionally higher ASDRs each year supports the need for ongoing efforts to improve the management of TAA in this group of patients.

Limitations

There are some limitations to this study that should be acknowledged. As with all administrative databases, the dataset used in this study is subject to coding errors, despite the rigorous training that clinical coders undertake to translate data, which may have influenced the results. However, in the absence of randomised trial data, the data presented in this study represent the best available evidence to ascertain the efficacy of TEVAR. The trends are also largely in keeping with two HES population based studies of an earlier time period.[5,35] Both ICD-9/10 and OPCS-4 codes are found to be wanting; neither diagnostic nor procedural codes separate the anatomical segments of the aorta sufficiently to reflect contemporary endovascular practice, which has undergone significant evolution to treat specific segments of the aorta, affecting the interpretation of the dataset. The lack of admission and operative data stratified by age and gender, and the lack of mortality data according to operative intervention precluded further understanding of the declining ASDRs and comparative analysis between OSR and TEVAR, respectively. Similarly, the lack of patient level anatomical and clinical data in these publicly available administrative sets precluded analysis of predictors of mortality and potential confounders; hence, in this observational study attributing causality to the findings was avoided. To focus on capturing predominantly degenerative aneurysms, it was elected to exclude patients under the age of 60 years. This will have led an intentional selection bias against the ascertainment of TAA, which is often the result of post-dissection dilatation in younger patients with aortopathies. While the absolute reduction in the number of post mortem examinations being conducted in England and Wales may exaggerate the declining trends in TAA mortality, the proportion of reported deaths requiring a post mortem has remained stable over the last 20 years.[44] Finally, the last 20 years have seen major changes in the delivery and organisation of vascular services in the UK. There has been centralisation and an appreciation of volume outcome relationships, with set standards for all hospitals offering aortic surgery endorsed by the Vascular Society of Great Britain and Ireland, and implementation through a national Quality Improvement Programme underpinned by a multidisciplinary approach that spans the disciplines of surgery, anaesthesia and critical care, and interventional radiology. These complex issues are also likely to have influenced the data presented herein but could not be quantified further due to data availability.

Conclusion

Contemporary analysis of a "real world" dataset has demonstrated a significant increase in hospital admissions for non-ruptured TAA in the last 23 years in England, paralleled by a major shift towards endovascular repair, and significant declining trends in aneurysm related mortality, irrespective of sex and age. The significant reductions in ASDR from ruptured and non-ruptured TAA in the endovascular era, particularly for women aged $>$ 80 years with ruptured disease affirm the positive impact of an endovascular approach to TAA.

CONFLICT OF INTEREST

None.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2022.07.003.

REFERENCES

1 Brown LC, Powell JT, Thompson SG, Epstein DM, Sculpher MJ, Greenhalgh RM. The UK EndoVascular Aneurysm Repair (EVAR) trials: randomised trials of EVAR versus standard therapy. *Health Technol Assess* 2012;**16**:1−218.

2 Fowkes FG, Macintyre CC, Ruckley CV. Increasing incidence of aortic aneurysms in England and Wales. *BMJ* 1989;**298**:33−5.

3 Al-Balah A, Goodall R, Salciccioli JD, Marshall DC, Shalhoub J. Mortality from abdominal aortic aneurysm: trends in European Union 15+ countries from 1990 to 2017. *Br J Surg* 2020;**107**:1459−67.

4 Sidloff D, Choke E, Stather P, Bown M, Thompson J, Sayers R. Mortality from thoracic aortic diseases and associations with cardiovascular risk factors. *Circulation* 2014;**130**:2287−94.

5 von Allmen RS, Anjum A, Powell JT. Incidence of descending aortic pathology and evaluation of the impact of thoracic endovascular aortic repair: a population-based study in England and Wales from 1999 to 2010. *Eur J Vasc Endovasc Surg* 2013;**45**:154−9.

6 Riambau V, Bockler D, Brunkwall J, Cao P, Chiesa R, Coppi G, et al. Editor's Choice − Management of Descending Thoracic Aorta Diseases: Clinical Practice Guidelines of the European

Society for Vascular Surgery (ESVS). *Eur J Vasc Endovasc Surg* 2017;**53**:4–52.
7 Upchurch Jr GR, Escobar GA, Azizzadeh A, Beck AW, Conrad MF, Matsumura JS, et al. Society for Vascular Surgery clinical practice guidelines of thoracic endovascular aortic repair for descending thoracic aortic aneurysms. *J Vasc Surg* 2021;**73**(1S):55S–83S.
8 Tsilimparis N, Debus ES, von Kodolitsch Y, Wipper S, Rohlffs F, Detter C, et al. Branched versus fenestrated endografts for endovascular repair of aortic arch lesions. *J Vasc Surg* 2016;**64**:592–9.
9 NHS Digital. Hospital Episode Statistics 2020. Available at: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics [Accessed 24th May 2021].
10 Office for National Statistics. Expenditure on healthcare in the UK. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthcaresystem/articles/expenditureonhealthcareintheuk/2015-03-26 [Accessed 20th November 2020].
11 Karthikesalingam A, Bahia SS, Patterson BO, Peach G, Vidal-Diez A, Ray KK, et al. The shortfall in long-term survival of patients with repaired thoracic or abdominal aortic aneurysms: retrospective case-control analysis of hospital episode statistics. *Eur J Vasc Endovasc Surg* 2013;**46**:533–41.
12 Holt PJ, Poloniecki JD, Thompson MM. Multicentre study of the quality of a large administrative data set and implications for comparing death rates. *Br J Surg* 2012;**99**:58–65.
13 Hartley A, Marshall DC, Salciccioli JD, Sikkel MB, Maruthappu M, Shalhoub J. Trends in mortality from ischemic heart disease and cerebrovascular disease in Europe: 1980 to 2009. *Circulation* 2016;**133**:1916–26.
14 Ash. Key dates in tobacco regulation 1962–2020. Available at: https://ash.org.uk/wp-content/uploads/2020/04/Key-Dates.pdf [Accessed 24th May 2021].
15 Office for National Statistics. Adult smoking habits in the UK: 2019. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/adultsmokinghabitsingreatbritain/2019 [Accessed 24th May 2021].
16 O'Keeffe AG, Petersen I, Nazareth I. Initiation rates of statin therapy for the primary prevention of cardiovascular disease: an assessment of differences between countries of the UK and between regions within England. *BMJ Open* 2015;**5**:e007207.
17 NCD Risk Factor Collaboration. Long-term and recent trends in hypertension awareness, treatment, and control in 12 high-income countries: an analysis of 123 nationally representative surveys. *Lancet* 2019;**394**:639–51.
18 Geisbusch S, Kuehnl A, Salvermoser M, Reutersberg B, Trenner M, Eckstein HH. Increasing incidence of thoracic aortic aneurysm repair in Germany in the endovascular era: secondary data analysis of the nationwide German DRG microdata. *Eur J Vasc Endovasc Surg* 2019;**57**:499–509.
19 McClure RS, Brogly SB, Lajkosz K, Payne D, Hall SF, Johnson AP. Epidemiology and management of thoracic aortic dissections and thoracic aortic aneurysms in Ontario, Canada: A population-based study. *J Thorac Cardiovasc Surg* 2018;**155**:2254–64.
20 Wang GJ, Jackson BM, Foley PJ, Damrauer SM, Goodney PP, Kelz RR, et al. National trends in admissions, repair, and mortality for thoracic aortic aneurysm and type B dissection in the National Inpatient Sample. *J Vasc Surg* 2018;**67**:1649–58.
21 Olsson C, Thelin S, Stahle E, Ekbom A, Granath F. Thoracic aortic aneurysm and dissection: increasing prevalence and improved outcomes reported in a nationwide population-based study of more than 14,000 cases from 1987 to 2002. *Circulation* 2006;**114**:2611–8.
22 Gouveia EMR, Silva Duarte G, Lopes A, Alves M, Caldeira D, Fernandes EFR, et al. Synchronous and metachronous thoracic aortic aneurysms in patients with abdominal aortic aneurysms: a systematic review and meta-analysis. *J Am Heart Assoc* 2020;**9**:e017468.
23 Hellgren T, Beck AW, Behrendt CA, Becker D, Beiles B, Boyle JR, et al. Thoracic endovascular aortic repair practice in 13 countries: a report from VASCUNET and the International Consortium of Vascular Registries. *Ann Surg* 2020. doi: 10.1097/SLA.0000000000004561 [Epub ahead of print].
24 Harky A, Kai Chan JS, Ming Wong CH, Bashir M. Open versus endovascular repair of descending thoracic aortic aneurysm disease: a systematic review and meta-analysis. *Ann Vasc Surg* 2019;**54**:304–15.
25 Patel R, Sweeting MJ, Powell JT, Greenhalgh RM. EVAR trial investigators. Endovascular versus open repair of abdominal aortic aneurysm in 15-years' follow-up of the UK endovascular aneurysm repair trial 1 (EVAR trial 1): a randomised controlled trial. *Lancet* 2016;**388**:2366–74.
26 United Kingdom ETI, Greenhalgh RM, Brown LC, Powell JT, Thompson SG, Epstein D. Endovascular repair of aortic aneurysm in patients physically ineligible for open repair. *N Engl J Med* 2010;**362**:1872–80.
27 Hellgren T, Wanhainen A, Steuer J, Mani K. Outcome of endovascular repair for intact and ruptured thoracic aortic aneurysms. *J Vasc Surg* 2017;**66**:21–8.
28 Makaroun MS, Dillavou ED, Kee ST, Sicard G, Chaikof E, Bavaria J, et al. Endovascular treatment of thoracic aortic aneurysms: results of the phase II multicenter trial of the GORE TAG thoracic endoprosthesis. *J Vasc Surg* 2005;**41**:1–9.
29 Fairman RM, Criado F, Farber M, Kwolek C, Mehta M, White R, et al. Pivotal results of the Medtronic Vascular Talent Thoracic Stent Graft System: the VALOR trial. *J Vasc Surg* 2008;**48**:546–54.
30 Chiu P, Goldstone AB, Schaffer JM, Lingala B, Miller DC, Mitchell RS, et al. Endovascular versus open repair of intact descending thoracic aortic aneurysms. *J Am Coll Cardiol* 2019;**73**:643–51.
31 Goodney PP, Travis L, Lucas FL, Fillinger MF, Goodman DC, Cronenwett JL, et al. Survival after open versus endovascular thoracic aortic aneurysm repair in an observational study of the Medicare population. *Circulation* 2011;**124**:2661–9.
32 Hammo S, Larzon T, Hultgren R, Wanhainen A, Mani K, Resch T, et al. Outcome after endovascular repair of ruptured descending thoracic aortic aneurysm: a national multicentre study. *Eur J Vasc Endovasc Surg* 2019;**57**:788–94.
33 Shimizu H, Hirahara N, Motomura N, Miyata H, Takamoto S. Current status of cardiovascular surgery in Japan, 2015 and 2016: analysis of data from Japan Cardiovascular Surgery Database. 4-Thoracic aortic surgery. *Gen Thorac Cardiovasc Surg* 2019;**67**:751–7.
34 Antoniou GA, Antoniou SA, Torella F. Editor's Choice – Endovascular vs. open repair for abdominal aortic aneurysm: systematic review and meta-analysis of updated peri-operative and long term data of randomised controlled trials. *Eur J Vasc Endovasc Surg* 2020;**59**:385–97.
35 von Allmen RS, Anjum A, Powell JT. Outcomes after endovascular or open repair for degenerative descending thoracic aortic aneurysm using linked hospital data. *Br J Surg* 2014;**101**:1244–51.
36 Conrad MF, Ergul EA, Patel VI, Paruchuri V, Kwolek CJ, Cambria RP. Management of diseases of the descending thoracic aorta in the endovascular era: a Medicare population study. *Ann Surg* 2010;**252**:603–10.
37 Dakour-Aridi H, Yin K, Hussain F, Locham S, Azizzadeh A, Malas MB. Outcomes of intact thoracic endovascular aortic repair in octogenarians. *J Vasc Surg* 2021;**74**:882–92.
38 De Rango P, Isernia G, Simonte G, Cieri E, Marucchini A, Farchioni L, et al. Impact of age and urgency on survival after thoracic endovascular aortic repair. *J Vasc Surg* 2016;**64**:25–32.
39 Czerny M, Funovics M, Ehrlich M, Hoebartner M, Sodeck G, Dumfarth J, et al. Risk factors of mortality in different age groups after thoracic endovascular aortic repair. *Ann Thorac Surg* 2010;**90**:534–8.

40 Ulug P, Powell JT, Warschkow R, von Allmen RS. Editor's Choice – Sex specific differences in the management of descending thoracic aortic aneurysms: systematic review with meta-analysis. *Eur J Vasc Endovasc Surg* 2019;**58**:503–11.
41 Lomazzi C, Mascoli C, de Beaufort HWL, Cao P, Weaver F, Milner R, et al. Gender related access complications after TEVAR: analysis from the retrospective multicentre cohort GORE® GREAT registry study. *Eur J Vasc Endovasc Surg* 2020;**60**:203–9.
42 Arnaoutakis GJ, Schneider EB, Arnaoutakis DJ, Black 3rd JH, Lum YW, Perler BA, et al. Influence of gender on outcomes after thoracic endovascular aneurysm repair. *J Vasc Surg* 2014;**59**:45–51.
43 Tumer NB, Askin G, Akkaya BB, Civelek I, Unal EU, Iscan HZ. Outcomes after EVAR in females are similar to males. *BMC Cardiovasc Disord* 2021;**21**:301.
44 Office for National Statistics. Coroners statistics 2019: England and Wales. Available at: https://www.gov.uk/government/statistics/coroners-statistics-2019/coroners-statistics-2019-england-and-wales [Accessed 24th May 2021].

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COUP D'OEIL

Atypical Type II Endoleak After EVAR: the Left Behind Artery

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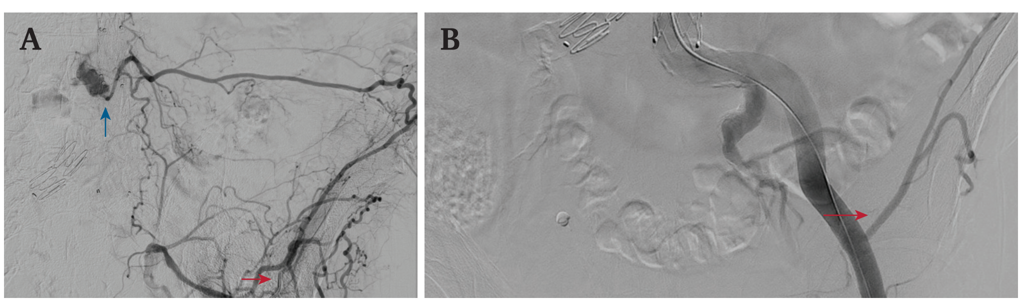

An 87 year old man with previous endovascular infrarenal abdominal aneurysm repair (Endurant IIS, Medtronic, Santa Rosa, CA, USA) presented four years later with a type II endoleak and aneurysm sac enlargement. Computed tomography angiography suggested and the angiography confirmed the origin of the endoleak. (A) A left lumbar artery (blue arrow) supplied by (A, B) a deep circumflex iliac artery collateral (red arrows). After catheterisation and microcatheter navigation (Marathon, Medtronic, Minneapolis, MN, USA), embolisation of the aneurysm sac was performed successfully using coils and ethylene vinyl alcohol.

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