Aneurysms: North America

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Abdominal Aortic Aneurysms

Based on an analysis of abdominal aortic aneurysm prevalence in 21 global regions, North America has one of the highest rates at 256 cases per 100,000 in the world; only Australasia has a higher rate [1]. This 2010 rate represents a substantial decrease from the 1990 prevalence estimate of 300 per 100,000, and possibly reflects a parallel drop in smoking patterns over this same time period [1]. Given current epidemiologic data, the United States Preventative Services Task Force recommends a single ultrasound screening of males aged 65–75 years who have smoked at least 100 cigarettes [2]. Selective screening based on medical and family history and goals of care is suggested for males in this age category who have not smoked. Screening is not recommended for women who have never smoked and the task force found insufficient data to recommend for or against screening of women aged 65–75 who have smoked.

Examination of the Nationwide Inpatient Sample (NIS) provides more granular data on the United States aneurysm population. The NIS is the largest American all-payer database and accrues data on roughly eight million discharges a year. Data from 2000, the first year endovascular aneurysm repair (EVAR) had a unique code, to 2010 includes 90,690 unruptured aneurysms and 11,288 ruptured aneurysms [3]. Seventy-nine percent of this cohort was male, 90 % was white and the mean age was 72.6 years. There was a 3 % in-hospital mortality rate for unruptured aneurysms with a median hospital length of stay of 5 days. Ruptured aneurysm patients, in contrast, had a 39 % in-hospital mortality and a 9-day median length of stay.

Stratifying by rupture status, 42,642 patients underwent open repair of unruptured aneurysms while 48,048 underwent endovascular treatment [3]. The latter cohort was more likely to be male (83 % vs. 76 %) and older (74 vs. 71 years). With EVAR, in-hospital mortality was better (1 % vs. 4 %, $p<0.001$) and length of stay was shorter (2 vs. 7 days, $p<0.001$). Nine thousand five hundred and thirty-eight patients had open repair of ruptured aneurysms and 1750 had endovascular repair [3]. Patients undergoing endovascular repair were older but there were no racial or age differences compared to the open cohort. As for unruptured aneurysms endovascular repair was associated with lower inpatient mortality (27 vs. 41 %, $p<0.001$) and a shorter length of stay (6 vs. 9 days, $p<0.001$).

There is a clear trend towards increasing use of EVAR in the US: in 2000, 5.9 % of unruptured and 0.8 % of ruptured aneurysms underwent

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endovascular repair compared to 77.8 % and 38.4 %, respectively, in 2010 [3]. One consequence of the rising frequency of endovascular repair is that open repairs are more likely to occur in anatomically complex patients. Barshes and colleagues used a prospectively maintained single-center registry to examine 1188 consecutive aneurysm repairs and found that, indeed, contemporary open aneurysm repair (2004–2010) was more likely to have greater blood loss and require suprarenal clamping than those that occurred in an earlier period from 1995 to 2004 [4]. Despite the apparent shift in complexity, there were no statistically significant changes in short- or long-term patient survival, length of stay, or complication rates.

Decreasing American trainee experience with open aneurysm repair is an additional effect of the changing paradigms of aneurysm therapy. In 2010, the average vascular surgery trainee in the US graduated with 21.7 open aneurysm cases, while the typical graduate in 2015 is expected to have completed only ten cases [5]. If current projections are accurate, this number will fall to only five cases by 2020 [5]. The predictions do not take into account fenestrated and branched endografts, which may further reduce open experience. These are understandable but nevertheless alarming changes that will be need to be addressed at a national level.

Descending Thoracic Aortic Aneurysms

As with abdominal aortic aneurysms, the therapy of descending thoracic aortic aneurysms has been revolutionized by the advent of stent grafts. This point is demonstrated by Kilic's analysis of NIS data spanning the decade beginning in 1998 [6]. This study includes 20,568 patients who underwent repair and covers the pre- and post-thoracic endovascular aneurysm repair (TEVAR) era. 17,780 aneurysms, or 86.4 %, were unruptured and the mean age overall was 64.7 years. 58.2 % of the cohort was male and the most common comorbidities were chronic obstructive pulmonary disease (COPD) (24.7 %), congestive heart failure (11.1 %), and stroke (10.9 %). The repairs took place principally at teaching hospitals (78.9 %) in an urban location (98.7 %).

Operative mortality decreased through the study period for all descending thoracic aortic aneurysm repairs [6]. The mortality associated with unruptured aneurysms diminished from 10.3 % in 1998 to 3.1 % in 2008 ($p < 0.001$) while peri-operative repair of ruptured aneurysms decreased from 52.6 % to 23.4 % ($p = 0.002$) over the same period. This improvement occurred despite the increase in comorbidities in the population: patients undergoing repair of unruptured aneurysms from 2005 to 2008 had higher rates of diabetes, renal insufficiency and COPD compared to those repaired from 1998 to 2004. They also had a higher Charlson index, a common weighted comorbidity scale. Similarly, patients undergoing repair of ruptured thoracic aneurysms had higher rates of renal insufficiency and worse Charlson indices in the second study period.

Diminished mortality in the face of sicker patients is likely largely due to more frequent endovascular repair. Multivariate analysis shows that open repair is independently associated with operative mortality [6]. Indeed, the rate of open thoracic aortic aneurysm repair went from 3.8 in 2005 to 4.4 per million in 2008, while endovascular repair increased from 1.0 to 6.2. A similar trend is seen for ruptured aneurysms. Overall repair rates increased from 2.2 in 1998 to 10.6 per million, suggesting that more patients were offered treatment in the endovascular era despite an overall worsening of their comorbid status.

The results of endovascular repair must be viewed critically, however. Goodney and colleagues used Medicare data from 1998 to 2007 to examine both perioperative and long-term outcomes [7]. This included 12,573 open repairs and 2732 endovascular repairs. 1307 (1008 open and 299 endovascular) were for ruptured aneurysms while the remainder was for intact aneurysms. They found that 30-day operative mortality was comparable between endovascular and open approaches for intact aneurysms: 6.1 % versus 7.1 % ($p = 0.07$). However there was a clear difference favoring endovascular therapy in ruptured aneurysms: 28.4 % vs. 45.6 % ($p = 0.0001$).

The survival advantage associated with endovascular repair of intact aneurysms disappears within 1 year once the results are adjusted for age, sex, race, timing of procedure, and Charlson index. Indeed, patients undergoing TEVAR have worse 5-year survival than those who undergo open repair (79 % vs. 89 %). The authors noted similar findings for repair of ruptured thoracic aortic aneurysms, with a disappearance of the TEVAR advantage within 90 days of surgery. The ability to repair aneurysms in sicker patients via TEVAR may not yield a long-term survival advantage, a topic that merits further investigation.

Thoracoabdominal Aortic Aneurysms

In contradistinction to abdominal and thoracic aortic aneurysms, data on national trends of thoracoabdominal aortic aneurysm (TAAA) therapy are sparse. Broadly, there are three principal categories of repair—open, endovascular, and hybrid—each of which has its advocates.

Cowan used 1988–1998 NIS data to examine trends in open repair [8]. While the overall mortality for the cohort of 1542 patients was 22.3 %, he found a statistically significant improvement in in-hospital mortality from 1988–1993 (25.7 %) to 1994–1998 (19.3 %). Mortality was significantly higher in low-volume hospitals and for low-volume surgeons. Indeed, there are multiple single-center reports from high-volume institutions with exceptionally low mortality and morbidity [9, 10]. This observation is particularly noteworthy given that only 32.8 % of TAAA repairs were performed at high-volume centers [8].

There is no quintessential North American approach to TAAA repair. There appears to be a trend away from the historical "clamp and sew" technique for open repair toward a greater use of left heart bypass [11]. Deep hypothermic circulatory arrest is typically reserved for patients with more complicated aortic anatomy, particularly in the area of the planned proximal anastomosis. Cerebrospinal fluid drainage remains a mainstay of efforts to prevent spinal cord ischemia, and is one of few strategies to be well-supported by the literature [12, 13]. Monitoring of motor- and somatosensory-evoked potentials has also been gaining in popularity in the more recent era [11, 14].

Using the 2005–2008 NIS database, Liao et al. reviewed trends on open surgical repair of TAAA, along with a combined group of patients undergoing either endovascular or hybrid repair [15]. The report included 2911 open and 1838 endovascular repairs, with the latter group including an unknown number of hybrid repairs. The authors found that the incidence of open repair rose from 7.5/100 patients in 2005 to 10.1/100 patients in 2008, a non-significant increase. The rate of endovascular or hybrid repair, in contrast, increased from 1.4 to 6.3 per 100 cases ($p < 0.0001$).

Current era endovascular repair of TAAA is typically achieved with fenestrated stent grafts, which often take several weeks to be custom manufactured to match the patient anatomy. This technique is limited to high volume centers and has incomplete long-term follow up. The Cleveland Clinic reported a series of fenestrated endovascular repairs for 258 juxtarenal and 349 type IV TAAAs [16]. Of these, 46.5 % required an SMA fenestration or scallop, 31.1 % had a celiac scallop, and 9.6 % had a supraceliac landing zone. Technical success was 97 % and 8-year aneurysm-related mortality was only 2 %. Spinal cord injury occurred in only 1.2 %.

Hybrid TAAA repair usually involves open surgical debranching of the visceral and/or arch vessels followed by interval stent graft deployment. This approach is intended to preserve some of the advantages of endovascular repair, such as avoidance of a thoracoabdominal incision, aortic cross-clamping and prolonged visceral ischemic times, while still allowing execution of the operation without the need for custom-made stent grafts. Kabbani et al. reported an experience of 36 hybrid repairs, including 31 TAAAs and two pararenal aortic aneurysms [17]. Two patients did not go on to receive the endovascular component after debranching because of death or prolonged recovery. Three patients received a single-stage procedure. In-hospital mortality was 8.3 % and 6-month survival was 80 %. There were no cases of permanent paraplegia. Other authors have

noted less favorable results and enthusiasm for hybrid repair of TAAA has considerably dimmed in recent years as the substantial associated operative morbidity and mortality has become more evident.

Popliteal Artery Aneurysms

Popliteal artery aneurysms are increasingly being repaired using endovascular means. An analysis of Medicare claims from 2005 to 2007, including 2962 repairs, showed an increase in endovascular repairs from 11.7% in 2005 to 30.9% in 2007 ($p<0.0001$) [18]. There were significantly more males in the open cohort and more octogenarians in the endovascular cohort but otherwise no differences. In-hospital, 30-day, and 90-day mortality were comparable in both groups. Postoperative complications were also equivalent, although the types of complications were distinctive. The open group had more cardiac, pulmonary, and infectious complications while the endovascular group had more hematomas. The 30- and 90-day rates of reintervention, including thrombolysis, repeat angiogram, and thromboembolectomy, were considerably higher in the endovascular group (7.42% vs. 2.11% and 11.84% vs. 4.55%, $p=0.001$), respectively. Predictably, length of stay was higher in the open group (4 days vs. 1 day, $p<0.0001$) while hospital charges were higher in the endovascular group ($35,052 vs. $ 28,298, $p<0.0001$).

Eslami et al. used data from a prospectively maintained multicenter American and Canadian registry, the Vascular Quality Initiative, to gain another perspective on repair of asymptomatic popliteal aneurysm. The report focused on 221 open and 169 endovascular repairs undertaken between 2010 and 2013 [19]. The endovascular group was an older cohort (mean age of 73.5 vs. 68.4), with more smokers, congestive heart failure, and COPD, but fewer prior lower extremity bypasses. Outcomes were superior in the open group; specifically, those undergoing open repair had a lower 1-year risk of major adverse limb events (MALE, a composite of major limb amputation and major reinterventions, HR 0.35, $p=0.02$), MALE and 30-day postoperative death (HR 0.28, $p=0.002$), and loss of primary patency (HR 0.25, $p=0.001$). The Vascular Quality Initiative database lacks some salient information, such as diameter of bypass conduits and the types and lengths of stents, which could feasibly impact outcomes. The Open Versus Endovascular Popliteal Artery Aneurysm Repair (OVER-PAR) trial is a multicenter, randomized trial that will shed more light on the role of endovascular stent grafting in the treatment of popliteal aneurysms [20].

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