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Outcomes of Elective Abdominal Aortic Aneurysm Management: Open Surgical versus Endovascular Repair

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Abstract

Introduction: Abdominal aortic aneurysm (AAA) is a disease with high mortality and morbidity. Evidence-based screening guidelines and elective repair options are crucial to mitigate the risk of rupture. Two primary techniques exist in the treatment of AAA. The open surgical repair method was standard of care until introduction of endovascular aneurysm repair in the 1990s. Endovascular aneurysm repair has become the mainstay of treatment of abdominal aortic aneurysms due to its minimally invasive approach and improved perioperative outcomes. Long-term overall survival outcomes are similar between the two approaches.

Methods: A systematic search of PubMed was conducted to review relevant articles comparing outcomes between open surgical repair versus endovascular aneurysm repair in the treatment of unruptured AAA.

Background: Patient-centered outcomes drove this research to better understand short-term and long-term findings between the two techniques. This literature review compares and contrasts the differing types of repair and outlines mortality rates, infection, hemorrhage, colonic ischemia, reintervention, secondary rupture, postoperative surveillance, and risk of future malignancy.

Conclusion: Evidence from the literature continues to support the use of endovascular aneurysm repair in the management of unruptured abdominal aortic aneurysm. Endovascular repair remains superior to open repair in perioperative outcomes and short-term mortality. Open surgical repair is still considered definitive treatment for AAA and is associated with less future interventions and risk of secondary rupture.

Introduction

Abdominal aortic aneurysm (AAA) is a disease that can result in catastrophic outcomes if not properly diagnosed and treated. Aneurysmal dilation of the abdominal aorta typically occurs below the renal arteries and often resides undetected except in the case of rupture. AAA is typically defined as lumen dilation that exceeds 3.0cm or >50% of the normal-caliber adjacent aorta.[1] Aneurysms develop due to gradual weakening of the arterial wall, often this is due to underlying hypertension or atherosclerosis.[2] Additional risk factors for AAA include tobacco use, male sex and family history.[2] Complications of AAA include ischemic and embolic events, in addition to rupture which causes massive hemorrhage and shock. Ruptured AAA is the third leading cause of sudden death in men older than sixty.[2] The incidence of AAA is increasing in the United States, with an aging population as a major contributing factor.[1] Screening ultrasound is recommended by the United States Preventative Services Task Force for men ages 65-75 years old who have ever smoked.[2] The rise in AAA cases makes it imperative that providers understand recognition of disease and the appropriate treatment interventions to reduce AAA-related morbidity and mortality.

An evidence-based treatment algorithm is necessary due to the high morbidity and mortality associated with AAA. Smaller aneurysms are typically monitored for interval growth and intervention is recommended at 5.5cm in asymptomatic men and 5.0cm in asymptomatic women.[2] Rapidly expanding interval growth along with ischemic or embolic complications are also indications for repair. Symptomatic AAA, including back or abdominal pain, also warrants an elective repair.[2] Open surgical repair (OSR) was first completed successfully in the 1950s and was the mainstay of treatment until the early 1990s with the introduction of endovascular aneurysm repair (EVAR).[3] EVAR offered a less invasive approach compared to OSR with improved perioperative outcomes and a viable option for patients unsuited for an OSR due to other comorbid conditions or suboptimal anatomic considerations. EVAR is now the first line therapy for most patients undergoing an elective AAA repair, with >70% undergoing EVAR versus OSR.[4]

It is important to outline the major differences between the two elective AAA repair techniques. OSR takes place in the operating room and consists of a patient being under general anesthesia, while EVAR often occurs in interventional radiology with the use of fluoroscopy. In an open repair, a large vertical incision is utilized to gain access to diseased aortic lumen, versus with EVAR percutaneous access is obtained via the common femoral artery.[5] With OSR the aneurysm is removed and replaced by synthetic graft material, which is sewn to the native vessel lumen, while EVAR consists of a stent deployment sealing off the aneurysmal sac but leaving it in place (see appendix figure 1). Patients are typically admitted to the hospital and monitored for several days with an OSR and monitored for one to three days after EVAR.[5] Depending on the location of the aneurysm, for both OSR and EVAR, the inferior mesenteric or renal artery may be removed from the diseased portion of the aorta and transplanted onto a healthy portion of native lumen to ensure proper perfusion to distal sites.[5]

OSR and EVAR are two viable and widely used options for the prophylactic treatment of unruptured AAA. This literature review seeks to examine the optimal method for elective AAA intervention and compare patient-centered outcomes between the two techniques. The evidence that will be presented in this thesis aims to compare OSR and EVAR as they relate to morbidity and mortality, perioperative complications, rate of recurrence, need for serial imaging, potential subsequent secondary interventions and long-term outcomes including risk for future malignancy. As this paper will demonstrate, the compiled evidence continues to support the use of EVAR under most settings due to its minimally invasive approach and improved perioperative outcomes. The literature presents some conflicting conclusions regarding the long-term outcomes between the two approaches including increased EVAR-associated secondary rupture and aortic-related interventions, thus creating ambiguity surrounding certain patients who may benefit more from OSR versus EVAR.

Background

The following literature review will begin by outlining certain preoperative criteria that may warrant an EVAR versus OSR and their associated outcomes. This review will seek to identify trends in both perioperative and long-term mortality among those receiving elective EVAR versus OSR. It will also outline various outcomes seen after OSR and EVAR including perioperative hemorrhage, infection, colonic ischemia, secondary rupture and the need for re-interventions. This review will also include patient-provider risk stratification tools to better decide between the two AAA repair techniques. These decision-making tools include the presence of comorbid diseases, the need for long term postoperative imaging surveillance and potential risk for future malignancy with CT-related radiation exposure.

Preoperative Planning

When comparing the outcomes between OSR and EVAR the review must begin with considerations of when to use each technique. Computed tomography angiography (CTA) is used to assess proper candidacy for EVAR versus OSR (see appendix figure 2).[6] Approximately 60% of patients are candidates for conventional EVAR, most often excluded due to anatomic limitations.[6] Such excluding anatomic factors include angulated proximal AAA neck, extensive intramural thrombus, calcifications that would hinder endograft seal or inadequate iliofemoral access site.[6] Preoperative imaging also allows for the assessment of aneurysm morphology, patency and relevant visceral vessels that may be impacted by the stent delivery, deployment or fixation.[6]

Standard EVAR is not the optimal treatment of choice when it comes to hostile anatomy. Specifically, conical aortic necks have been associated with standard EVAR failure.[7] The conical aortic neck is defined by a short, tapered proximal neck. This poses an issue because the stent will not form a proper seal against the native aortic lumen making the risk for type 1 endoleak very likely.[7] Endoleaks and their implications will be further discussed within reinterventions section. A retrospective, multicenter study concluded that patients treated with standard EVAR and had the presence of conical necks was strongly associated with proximal failure of the stent due to endoleak. The use of newer fenestrated EVAR devices have been utilized in the setting of unfavorable aortic neck angulation and allow for the treatment of complicated aneurysms.[6]

The advances in EVAR technology has expanded its role to be able to treat more complex AAAs that would have historically been managed by OSR. A comparative study sought to assess perioperative outcomes in the treatment of anatomically complex EVAR versus complex OSR as they compare to standard infrarenal EVAR. Complex OSR had the highest perioperative mortality (6.6%), followed by complex EVAR (3.4%), then standard infrarenal EVAR (1.5%).[8] Overall, complex OSR resulted in increased 30-day mortality rates, increased risk of postoperative acute kidney injury and risk of any complication when compared to complicated EVAR cases. The anatomically uncomplicated standard EVAR was associated with favorable 30-day mortality and low rates of complication including acute kidney injury.[8] This study is promising that modern EVAR approaches are able to treat anatomically complex cases and improve perioperative outcomes when compared to complicated OSR cases. Further research is warranted to assess if these benefits are maintained at long-term intervals.

Adequate pre-procedure planning is necessary to select the appropriate approach in the management of unruptured AAA to optimize patient outcomes. Preoperative imaging and anatomic considerations allow surgeons to outline the most appropriate method. Historically, the indication for OSR relied heavily on suboptimal anatomic variations. Modern EVAR devices have proved able to improve perioperative outcomes in complicated cases compared to complicated OSR. Long-term studies are still needed to evaluate if this early advantage is maintained.

30-day and Long-Term Mortality

Mortality has been the primary endpoint used to measure outcomes between OSR and EVAR. Early randomized control trials including EVAR-1, ACE, OPEN and DREAM studies were instrumental in the wide acceptance for the use of EVAR in the treatment of unruptured AAA. The short-term mortality and improved perioperative outcomes were apparent early on and made EVAR the eventual standard of care. In a meta-analysis of 51 studies, the pooled 30-day mortality was 1.16% for EVAR and 3.27% for OSR.[9] This same study showed no significant difference in all-cause long-term mortality between the two techniques (see appendix table 1). Another meta-analysis concluded 30-day mortality to be significantly lower with EVAR compared to OSR, yet long-term findings showed an association between EVAR and increased aneurysm-related mortality, reintervention rates and secondary rupture.[10] A third meta-analysis primarily focused on the outcome of mortality showed similar results with increased long-term mortality at 5-9 years after EVAR in addition to higher rates of reintervention and rupture compared to OSR.[11] Limitations of these meta-analyses include the use of data in which patients underwent elective AAA repair procedures (either OSR or EVAR) between 2000-2008. Researchers criticize that these rates do not adequately represent current technology, which warrants future randomized control trials to be conducted to further understand the long-term outcomes of newer EVAR products and devices. The current evidence presented still suggests an early mortality benefit with EVAR, yet in the intermediate and long-term this advantage is lost and OSR appears to be superior in late aortic-related mortality.

Mortality trends among EVAR and OSR continue to have heterogeneity prompting the need for further research. The literature has solidified that perioperative outcomes and 30-day mortality rates favor EVAR versus OSR. This early advantage for EVAR is somewhat lost at the intermediate and long-term outcomes when aortic-related mortality rates among patients treated with EVAR surpass those treated with OSR.[12] This may be in part to higher reintervention rates and secondary rupture associated with EVAR.[10,11] Aneurysm-related late survival outcomes are worse with EVAR, yet the fourteen year follow-up from the randomized control OVER trial did not notice significant differences in the long-term all-cause mortality between the OSR or EVAR groups.[12] These results are why some researchers conclude similar long-term outcomes between the two approaches in regard to all-cause mortality, yet the late aortic-related mortality is higher with EVAR. The mortality trends between EVAR and OSR require the surgeon to better risk stratify which patients may benefit greater from improved short-term versus long-term mortality rates. The decision to EVAR versus OSR should not rely on mortality rates alone, but also incorporate evidence on significant perioperative complications associated with the two approaches.

Mortality and Concurrent Comorbidities

Another aspect of mortality that is important to address when comparing outcomes between EVAR and OSR is the preoperative surgical risk and additional comorbidities. The question remains if certain patient demographics may have improved outcomes if treated with

OSR versus EVAR. Historically, to mitigate poorer long-term outcomes that are associated with EVAR, some surgeons may offer younger patients with long life expectancy and low surgical risk the OSR option. Though this makes theoretical sense and is still seen in practice, one retrospective study concluded that among patients <60 years old EVAR offered similar long-term survival compared to OSR.[13] Results of a randomized control trial also reported higher long-term survival rates among younger patients (<70 year old) who underwent EVAR compared to OSR. And among older patients EVAR resulted in lower long-term survival compared to those receiving OSR.[12] EVAR is often thought to be more beneficial to older or medically frail patients due to its minimally invasive approach, yet there are some conflicting trends in the literature that may suggest the decision to EVAR versus OSR is not so binary.

A meta-analysis of four randomized control trials created subgroups to further evaluate the relationship between comorbidities and elective AAA repair, since often EVAR is seen as superior for patients with comorbidities due to early survival advantage. This study concluded that there was no early survival advantage among patients receiving EVAR who also had concurrent moderate renal dysfunction or coronary artery disease.[3] Additionally, smoking, diabetes, BMI or preoperative morphological aneurysm characteristics did not show any association with an increase or decrease in mortality rates.[3] One subgroup who conferred an early survival advantage due to treatment with EVAR was patients with peripheral arterial disease, though in intermediate follow-up (6 months-4 years) OSR had the survival advantage.[3] Again, these findings suggest that surgeons should not rely solely on a presumed early survival advantage of EVAR to be present in their patients with comorbid conditions. More research is needed to further assess if patients with certain comorbidities may experiences improved mortality rates between the OSR versus EVAR approach.

Perioperative Outcomes: Hemorrhage & Infection

It was clear after the introduction of EVAR the advantage it provided for improved perioperative outcomes and short-term mortality. The minimally invasive approach improves abdominal aneurysm-related mortality within the first 30 days when compared to OSR.[12] EVAR has also been associated with shorter procedure times, less ventilator support, less operative bleeding and a reduction in the need for perioperative blood transfusions.[14] The open repair approach still holds a greater likelihood for bleeding and retroperitoneal hemorrhage in the immediate postoperative period compared to EVAR.[4] The risk of intraoperative bleeding is present with both OSR and EVAR technique, yet the risk is far greater in the OSR approach.

Infection of the aortic graft/stent material post elective repair with either OSR or EVAR is a rare but life-threatening complication. Reported rates of infected EVAR grafts are between 0.2%-0.7% and are as high as 2% with OSR aortic grafts.[15] The overall mortality for aortic graft/stent infections range between 10-40%.[15] A retrospective analysis sought to address the outcomes of infected graft material between EVAR and OSR groups, with the primary endpoint being 30-day mortality. The mean time between initial procedure and onset of graft infection presentation was 27.9 months in the EVAR group and 107.8 months in the OSR group.[15] EVAR patients were more likely to present with active bleeding and rupture of AAA sac, and 87.5% of EVAR patients clinical presentation was abdominal pain.[15] All patients in the study underwent explantation of the infected device and then was revascularized with a new graft. Overall postoperative mortality was 23.1% (37.5% for EVAR and 0% for OSR).[15] Higher mortality rates among the EVAR group was theorized to be caused by supraceliac clamping and higher rates of acute kidney injury.[15] Graft infection rates were higher among OSR patients but EVAR patients experienced higher 30-day mortality rates after surgical intervention. Graft infection is an often-fatal complication of elective AAA repair that is seen more commonly with OSR technique, yet EVAR has worse outcomes in regard to mortality rates.

Colonic Ischemia

Another significant complication following elective AAA repair associated with high morbidity and mortality is colonic ischemia (CI). The incidence of CI following either OSA or EVAR is rare, but due to its high likelihood of poor outcomes it's crucial to understand the contributing risk factors and underlying pathophysiology.[16] Disruption of blood flow to the colon after AAA repair occurs due to a variety of factors, one being compromise of the inferior mesenteric artery (IMA). The IMA branches anteriorly off the distal aorta just proximal to the bifurcation. This anatomic location makes it amenable to direct trauma or closure during OSR or EVAR, resulting in subsequent decreased bowel perfusion.[16] Other etiologies of CI after AAA repair include microembolization of the bowel, embolized hypogastric artery, trauma to the colon, retroperitoneal hemorrhage, delayed reperfusion and prolonged hypotension.[16] The greatest risk factor for the development of CI is a ruptured AAA presentation.[8] Other risk factors include female gender, hypertension, heart failure and current smoking.[8] Along with these known risk factors it is important to discuss the incidence of CI observed among patients undergoing elective OSR or EVAR.

The introduction of EVAR and its widely adopted application for both elective and ruptured AAA repair have markedly decreased the rates of CI. In a retrospective study with 45,474 patients identified undergoing infrarenal AAA repair, total postoperative CI incidence was 1.9%.[17] OSR was associated with a three times greatest risk of developing CI compared to those who received EVAR. Of those who developed CI, 6.2% underwent OSR and 0.8% received EVAR.[17] Over one third of the patients who were diagnosed with CI postoperatively died within 30 days of the AAA repair, this further alludes to the severity of this complication and the need for methods to mitigate risk.[17] A meta-analysis including thirteen studies and 162,750 patients also concluded the use of EVAR is associated with a reduced rate of CI when compared to OSR.[18] Incidence of CI in the EVAR group was 0.5-1% compared to 2.1-3.6% in the OSR group.[18] The cases of CI resulted in variable mortality as high as 73% and reintervention rates as high as 54%.[18] Limitations of the meta-analysis included a high degree of heterogeneity between the studies. Overall, there is significant evidence within the literature to concur that EVAR reduces the risk of CI when compared to an OSR.

Reintervention & Endoleak

The literature confirms that EVAR is associated with less incidence of perioperative complications like infection, hemorrhage and colonic ischemia, however long-term complications and reinterventions are seen more frequently with EVAR versus OSR. The risk of reintervention following elective AAA repair exists for both OSR and EVAR techniques. Early reintervention within 30 days is significantly more likely to occur after OSR compared to EVAR which has more late reinterventions. The 30-day reintervention after either OSR or EVAR were associated with 10 times increase in postoperative mortality.[19] Among patient receiving EVAR up to one in five people will undergo revision within the first five years.[20] EVAR requires lifelong surveillance imaging which in part may contribute to the higher late reintervention rates when compared to OSR, which does not require serial imaging.[21] One of the major complications being screened for on annual endograft imaging is the development of an endoleak, which is a complication unique only to EVAR and can occur at any time postoperatively. Endoleak is defined by persistent blood flow into the aneurysmal sac post stent deployment, which allows for potential sac expansion and secondary rupture (see appendix figure 3).[22] Endoleaks can occur if the covered stent graft material does not completely exclude the aneurysmal sac (type I), collateral circulation often from IMA or lumbar arteries supply aneurysmal sac (type II), endograft rupture/failure (type III) or porous flow through endograft that supplies the sac (type IV).[22] Type II endoleak is the most common type and occurs in 10-25% of EVAR patients and may require additional interventions.[22]

Research has been conducted to better predict and understand the rate of secondary interventions among OSR and EVAR techniques, along with risk factors that may be predictive of endoleak or the need for future repair. The Open Versus Endovascular Repair (OVER) trial randomized patients between 2002-2011 to an EVAR treatment arm or an OSR group. Patient outcomes were followed through 2016 and reported data on overall survival and secondary interventions. Long-term overall survival was similar among the two groups, but 26.7% of patients in the EVAR arm underwent a secondary procedure compared to 19.8% in the OSR group.[3] Endoleak was the most common reason for EVAR secondary intervention while OSR reintervention was most commonly due to incisional hernia.[3] The OVER trial also found an association between larger aneurysm diameter preoperatively and the need for future secondary intervention after EVAR.[23] Among those in the trial undergoing EVAR, 30.5% developed an endoleak and 20% of these developed after two years postoperatively.[23] Of those with confirmed endoleak 53% resolved spontaneously and only 9.8% of endoleak patients underwent a secondary procedure to correct this.[23] The study also concluded that the presence of an endoleak or even aneurysm sac dilation was not associated with increased all-cause mortality.[23]

Another study sought to assess the St George's Vascular Institute (SVGI) score and its role in predicting which patients may need to undergo secondary interventions post EVAR or OSR. It is calculated by adding the maximum aortic diameter to the maximum common iliac artery diameter and classifies patients with low or high secondary intervention risk.[24] Patients were randomized to either an EVAR or OSR arm and SVGI scores were obtained preoperatively then the groups were followed between 2000-2009 for the need of secondary interventions. Within both groups the SVGI score was able to gauge high risk patients and predict the need for reintervention, based on the anatomic characteristics of the preoperative aneurysm.[24] OSR was associated with higher wound-related interventions and hematoma evacuation while EVAR was associated with higher rates of graft-related interventions, most commonly type II endoleak.[24] These findings are consistent with a retrospective single institution study that concluded EVAR has lower perioperative reinterventions but higher late and graft interventions compared to the OSR group.[4]

Results of current meta-analyses conclude that EVAR was associated with higher rates of late secondary interventions compared to OSR.[10,11] One criticism of trials reporting on reintervention rates between OSR and EVAR is that incisional-related secondary interventions associated with OSR are often excluded from data sets since it is not necessarily a graft-related reintervention.[21] Another critical limitation is that current meta-analyses addressing reintervention rates present data on endografts that were placed 1999-2011, not taking into account the newer products and techniques that likely provide better outcomes.[25] In any case, the use of EVAR still holds the tangible complication of endoleak which could put patients at greater risk for late secondary repairs, especially in the case of larger preoperative aneurysm size. The presence of endoleak may be insignificant in cases when the aneurysmal sac remains stable, as half of endoleaks can resolve spontaneously and those that are treated do not improve overall mortality. OSR does not hold the risk of endoleak but may require more incisional-related revisions. Preoperative planning with elective AAA repair warrants a discussion on potential development of endoleaks and the need for continued surveillance and possible secondary interventions. Ultimately, the goal of these EVAR reinterventions are to treat endoleaks and prevent the serious complication of secondary recurrence and rupture.

Secondary Recurrence & Rupture

Secondary recurrence and rupture are rare but serious complication following elective AAA repair with either OSR or EVAR. It is more often seen after EVAR but is far less common than reintervention or endoleak. The risk of late aneurysm rupture after EVAR is as high as 3%.[20] Larger cohort studies estimate the rate of rupture after EVAR to be between 0.5-1.2%.[26] Ruptures are most often due to persistent endoleak, which is why rates of secondary rupture are higher among patients with EVAR versus OSR.[26] In a retrospective analysis of 679 patients receiving EVAR and 199 patients receiving OSR, 22 patients in the EVAR group ruptured at a mean timeframe of 4.9years (range 1.7-13.2 years), and during this same timeframe there were no ruptures in the OSR group.[26] Studies have shown that patients who present with ruptured AAA status post EVAR tend to be more hemodynamically stable with less severe presenting symptoms compared to counterparts who present with ruptured AAA and did not receive a prior EVAR.[26] The research continues to support the use of EVAR as an elective AAA repair option even though it has higher secondary rupture rates when compared to OSR. Continued imaging surveillance is recommended to evaluate for presence of endoleak, which is the main contributing risk factor for secondary rupture. Even in the case of a AAA rupture post EVAR patients have improved mortality rates compared to patients with AAA rupture and no prior history of EVAR, this is because the endograft creates greater hemodynamic stability on presentation.[26]

Though rare, it is in the literature that patients undergoing elective AAA repair with EVAR may require open conversion as a final option for certain EVAR complications. This conversion from EVAR to OSR is typically a last resort option often in the case of endograft infection, increasing aneurysmal sac size, endograft migration or persistent endoleak.[27] In a single retrospective study 13 late open conversions were indicated out of 513 consecutive patients treated with EVAR. The median time from initial EVAR to open conversion was 32.4 months, and there were no cases of operative mortality.[27] The most common indication was endoleak (61.5%), infection (30.8%) and migrations (7.7%).[27] Overall, the risk for secondary recurrence and rupture after EVAR remains rare and patients tend to fare better than counterparts with no prior EVAR. Surgical options like open conversion from EVAR to OSR still exist in certain cases of expanding sac size or persistent endoleak to prevent the risk of secondary rupture. Endoleak has major implications on the risk of secondary recurrence and rupture which makes postoperative imaging surveillance recommended for all patients undergoing EVAR.

Postoperative Imaging Surveillance

A striking difference between the postoperative management of OSR and EVAR is the need for long term imaging surveillance among patients who undergo EVAR. Imaging is warranted to evaluate for the presence of endoleak, increasing aneurysmal sac size, thrombosis, graft migration and kinking.[22] The early detection of these complications can help to guide prompt treatment. CTA remains the cornerstone of surveillance imaging among those post-EVAR, and it's usually completed 30 days, 6 months and 1-year post procedure.[22] CTA is considered the gold standard and utilized often within the first year to clearly delineate any endoleaks (see appendix figure 4), and then barring any complications requiring more aggressive monitoring patients undergo CT annually for life.

The major risk associated with annual CT is the radiation exposure, and in contrast ultrasound can offer a low cost and non-radiation option to patients.[22] Ultrasound is used to monitor interval growth in the aneurysm sac size or for the presence of endoleak (see appendix figure 5). Color and spectral Doppler are utilized to analyze directionality and inflow of any endoleaks present.[22] Similar to other ultrasound uses it carries a high specificity (95%) and low sensitivity (70%) due to heterogeneity of operator skill and technique in addition to artifacts and limitations due to large patient body habitus.[22] Additional pros and cons of CT versus US in the imaging of EVAR are presented in the appendix tables 2 and 3. Whether it be ultrasound or CT, researchers are still exploring the benefits and optimal guidelines surrounding yearly imaging surveillance among all patients post EVAR and understand they may not be binary.

Systematic review of 11 retrospective cohort studies encompassing 21,838 patients sought to better understand the effects of imaging surveillance after EVAR and its impact on reintervention and mortality. Results from the studies showed the groups that complied with serial EVAR imaging did not have decreased risk against secondary rupture or mortality compared to non-compliant or partially compliant EVAR imaging groups.[28] Findings also suggest that the imaging-compliant EVAR group were more likely to undergo reinterventions, even though these additional procedures did not increase overall survival.[28] This study concluded some EVAR patients may benefit greater from routine imaging surveillance compared to others. Assessing preoperative anatomy using the St George's Vascular Institute Score to predict reintervention risk, along with a normal first postoperative scan may suggest a low reintervention risk post EVAR.[28] Risk stratifying patients with specific parameters may allow for decreased imaging frequency in some groups.[28] It is known that patients are more likely to undergo reintervention procedures after EVAR compared to OSR, and the question still remains is this association due sheerly to the annual imaging surveillance recommendation for EVAR patients which allows the opportunity for increased secondary interventions. The lifelong surveillance imaging recommended with EVAR may in part be contributing to the higher reintervention rates compared to OSR, since OSR does not require the same serial imaging requirements. The CT imaging recommendation also raises the question if there is an associated between repeated radiation exposure and any increased risk for malignancy among EVAR patients.

Risk for Future Malignancy

The use of EVAR has reduced poor perioperative outcomes, but this early benefit may be lost due to an increase in late-mortality with EVAR versus OSR.[29] Researchers have posed the question if radiation exposure associated with EVAR both due to intraprocedural fluoroscopy and postoperative CT surveillance contributes to an increase in cancer rates compared to those with OSR.[29] In a large European cohort study, data was evaluated between 2005 and 2013 using the English Hospital Episode Statistics; 14,150 patients with EVAR and 24,465 patients with OSR were selected for review.[29] Results showed an increase risk in abdominal cancer within the EVAR arm compared to the OSR group. Interestingly, the EVAR groups who underwent routine postoperative CT surveillance had no increased risk of cancer compared to EVAR groups who did not receive regular CTs.[29] This suggests that the associated risk of abdominal cancer after EVAR may stem from the initial procedure itself and the use of fluoroscopy versus the surveillance imaging.[29] Limitations of the study include confounding, the multifactorial nature of cancer development and the inability to prove causation with the population-based cohort design.[29] Further research including randomized control trials are needed to adequately address this observed association between abdominal cancer and EVAR.

Methods

PubMed search was completed to obtain relevant literature to this research topic. Key word searches included "abdominal aortic aneurysm," "EVAR," "surgical repair," "endoleak," "mortality" and "ischemic colitis." Search results were limited to studies from the last twenty years. EVAR data was obtained from sources published within the last two years in order to account for improved surgical techniques and devices. Inclusion criteria for this literature review included evaluation of the authors study designs and interpretation of their presented data. The types of study designs evaluated in this review include randomized controlled trials, meta-analyses, prospective interventional studies, comparative studies and retrospective observational studies. Selected articles were independently reviewed, and the research findings were compiled for this paper.

Discussion

This outcome-driven literature review sought to outline what method is superior in the management of unruptured AAA. The consensus remains that EVAR is an appropriate first-line prophylactic treatment for elective repair of AAA. The minimally invasive technique improves perioperative outcomes and 30-day mortality rates when compared to OSR.[9,10] OSR is associated with increased operative times, retroperitoneal hemorrhage, increased blood loss and greater need for blood transfusions compared to EVAR.[14] Colonic ischemia is also more significantly associated with OSR versus EVAR, and outcomes can be fatal.[17] Graft infection is also a serious complication and seen more frequently with OSR approach, however mortality rates are worse for patients with EVAR.[15] The long-term mortality rates from the OVER trial concluded similar overall long-term mortality rates between EVAR and OSR groups, while Li et al. and Antoniou et al. noted a loss of early EVAR benefit due to increased later aortic-related mortality rates.

These meta-analyses also concluded greater rates of reintervention and secondary rupture associated with EVAR. For this reason, many surgeons still see OSR as a viable option for certain patients with low surgical risk, or for those unwilling to undergo surveillance imaging and the potential need for future interventions. Certain comorbidities and anatomic considerations are also contributing factors when deciding which repair technique serves most suitable.

The increase in late aortic-related mortality rates associated with EVAR stem from the increased reintervention rates and likelihood of secondary rupture. The most common indication for reintervention after EVAR is a type II endoleak, and most patients who experienced secondary ruptures were found to have an underlying endoleak. It's important to note that patients with ruptured AAA post EVAR tend present with less severe presenting features and are more hemodynamically stable compared to patients with no prior history of EVAR. While EVAR has high graft-related interventions, the most common reintervention after OSR continues to be incisional-related hernias and graft-related repairs remain low.[3] Patients undergoing EVAR must understand the risk of endoleak will always be present and lifelong surveillance imaging either with CT or ultrasound is warranted. There has not been an agreed upon timeframe for this routine endoleak screening to stop. The additional radiation exposure associated with annual CT has not been associated with an increased risk of malignancy among EVAR patients, yet some research suggests that initial radiation and use of fluoroscopy during the EVAR procedure itself may put patients at greater risk for future malignancy compared to OSR patients.

Implications for future practice based on this literature review must begin with a patient-provider discussion outlining both the OSR and EVAR method for AAA repair. The main procedural differences include percutaneous access versus open abdominal incision along with extraction of the diseased aortic segment versus leaving the aneurysmal sac in place. The lifelong need for serial imaging associated with EVAR must be discussed and the patient's willingness to comply should be gauged. Patients should also understand the higher risk of secondary rupture and reintervention that is associated with EVAR. OSR is still a viable option for low risk surgical candidates who may want to minimize future reinterventions or the need for annual imaging. Surgeons continue to risk stratify patients based off age and existing comorbidities to recommend the optimal elective repair technique.

Limitations within this literature review include meta-analysis data that includes information on devices placed primarily between the 2000-2008 window, thus making it difficult to account for the improvement of the EVAR graft material and placement techniques. Future research should include randomized control trials with the use of updated graft and stent materials to evaluate if this has any impact on long-term EVAR outcomes. Another major limitation is the lack of data in the literature on female patients. Though men are affected by AAA proportionally higher than women, women tend to have higher complication rates associated with AAA and after elective repair. More data is needed to better understand the best method of elective repair for women with unruptured AAA and if one method holds superior to the other.

Comparing outcomes between EVAR and OSR within the existing literature has validated both techniques as having a role in the treatment of unruptured AAA. EVAR remains the standard of care for the majority of patients. OSR requires additional perioperative risk stratification and inclusion of patient goals. Since both techniques have their relevance, surgeon competence needs to be maintained for both approaches. Further research with more subgroups including women warranted to better understand if any gender difference outcomes exist. Further research into reintervention and secondary rupture are also indicated to account for modern graft stent devices. There also remains heterogenicity among the best approach for elderly patients or those with comorbidities, allowing for more research to discern the best approach to improve patient outcomes in these subgroups.

Conclusion

The management of unruptured AAA has evolved dramatically since the turn of the century. Standard of care shifted from OSR to EVAR by the late 1990s and EVAR gained widespread acceptance after promising early randomized control trials. The early survival advantage of EVAR has rang true throughout its use, though research shows this is lost at intermediate and long-term intervals due to higher rates of aortic-related intervention and secondary rupture. Much of the large meta-analyses are based off data from outdated devices warranting new randomized control trials utilizing newer graft material to better understand late outcomes and reinterventions associated with EVAR.

EVAR, now with three decades of application behind it, has established its vital role in the treatment of both ruptured and intact AAA. The presented literature supports the use of EVAR to reduce both perioperative complications including hemorrhage, infection and colonic ischemia. In addition, the long-term all-cause mortality rates are similar to that of OSR. Patients who are medically frail or with multiple comorbid conditions have a viable option with EVAR if their surgical risk is too great for an OSR. The evidence presented also favors the use of OSR for patients with low to moderate surgical risk as it remains a more durable long-term repair option with fewer graft-related reinterventions compared to EVAR. The literature emphasizes surgeons maintain competency in the OSR technique due to its continued relevance in the treatment of unruptured AAA, and because the need for open conversion after EVAR still exists.

It's likely EVAR will remain the mainstay of treatment for elective AAA repair partly due to patient preference for the minimally invasive technique. The decision to EVAR versus perform an OSR still requires preoperative planning and risk assessment to optimize perioperative outcomes. Updated research should be conducted to evaluate the association between modern EVAR devices and late secondary ruptures and aortic-related reinterventions. Surgeons are hesitant to solidify EVAR as superior to OSR due to the heterogeneity of these late outcomes. Continued critically driven research with late aortic morbidity and mortality in mind will help to outline which elective repair method optimizes late patient outcomes.

The information presented in this literature review has important applications for future practice. The research presented suggests there is lacking evidence to claim EVAR as overall superior compared to OSR. Researchers and surgeons may question the long-term durability of EVAR now that some of its novelty has worn off and poorer outcomes have been established at late intervals. In future practice the OSR approach may gain greater utilization due to reduced risk for interventions or the need for lifelong surveillance.

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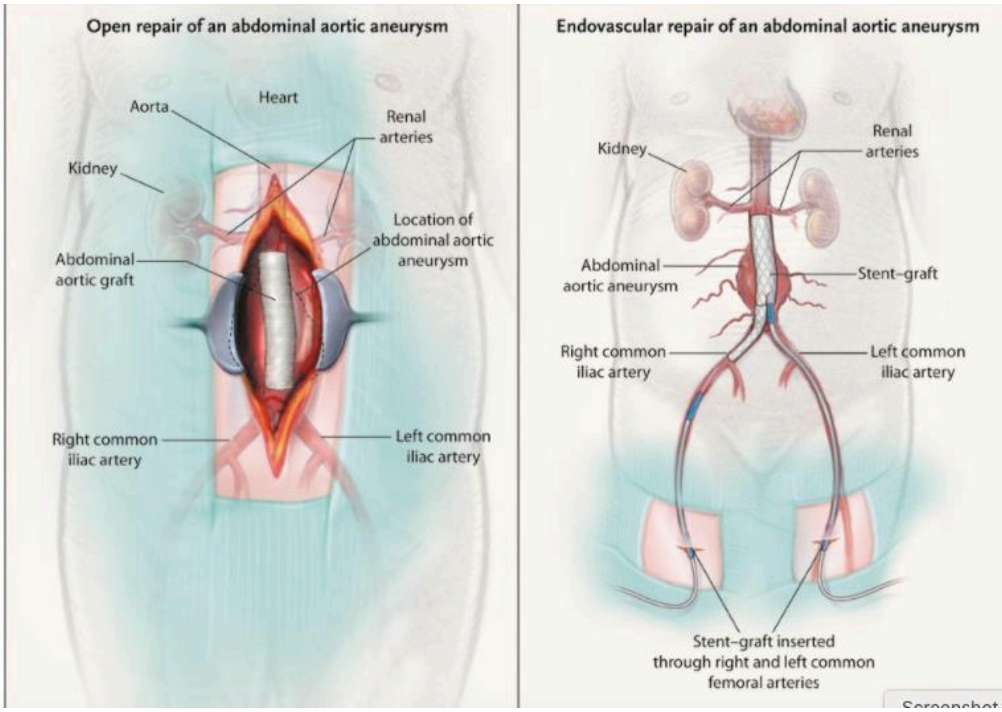
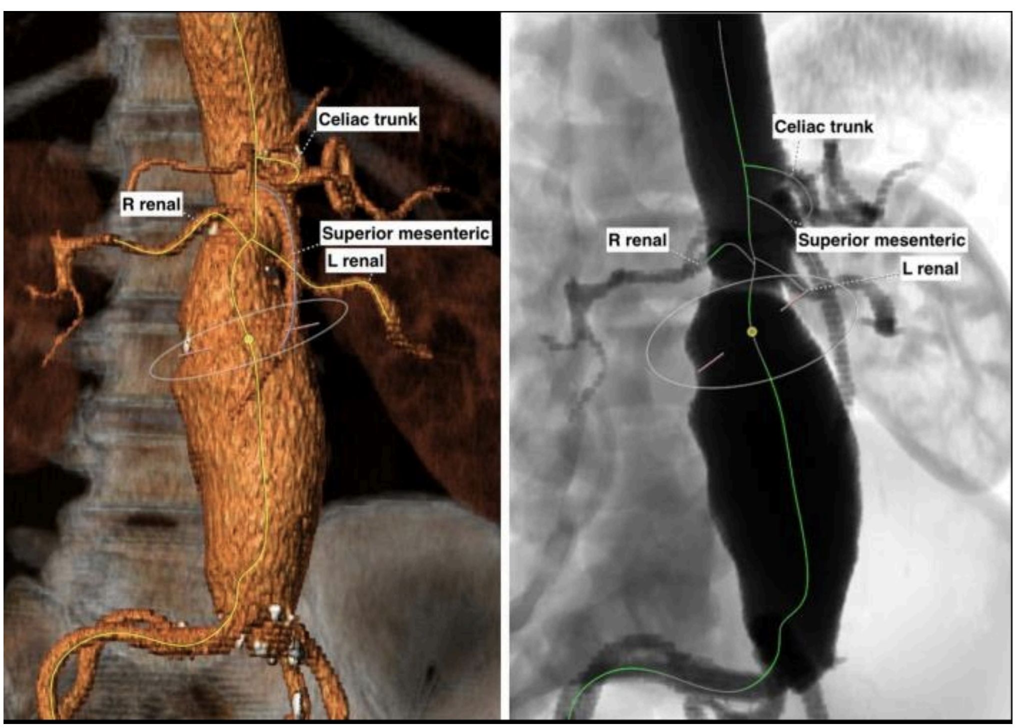
Appendix

OSR versus EVAR technique, Figure 1 [30]



Preoperative planning, Figure 2 [6]



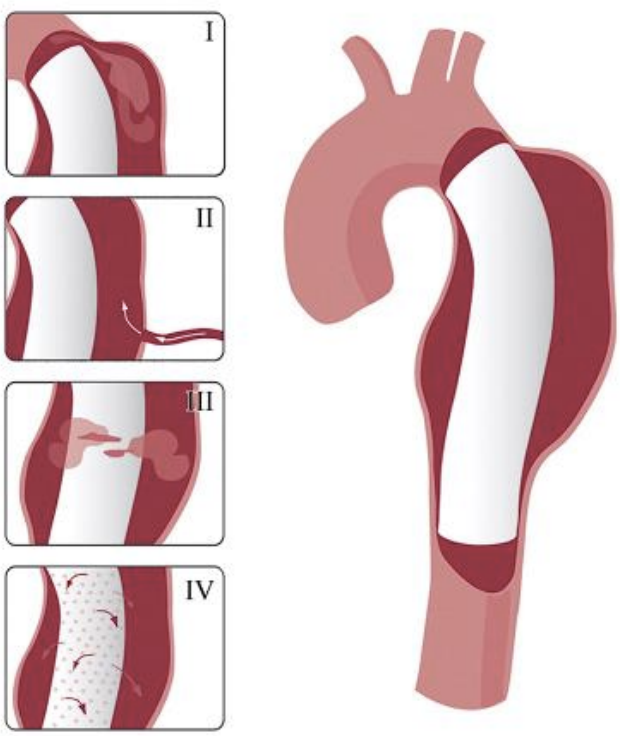
Mortality, Table 1[9]

Table 1 Relative survival ratios (observed : expected survival) for endovascular and open surgical repair of intact abdominal aortic aneurysms

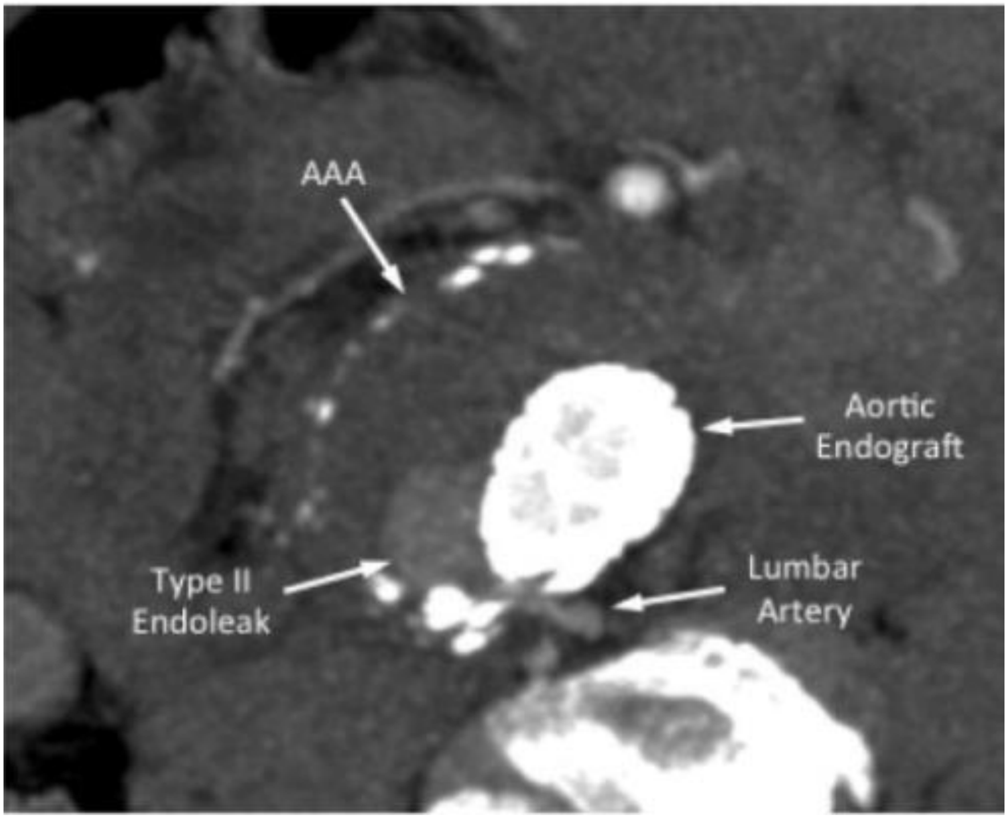
	Relative survival ratio		
	3 years	5 years	10 years
EVAR	0·94 (0·92, 0·96)	0·91 (0·87, 0·94)	0·76 (0·67, 0·86)
OSR	0·96 (0·95, 0·98)	0·91 (0·88, 0·94)	0·76 (0·69, 0·85)

Values in parentheses are 95 per cent confidence intervals. EVAR, endovascular aneurysm repair; OSR, open surgical repair.

Types of Endoleaks, Figure 3 [22]



CTA of Type II endoleak with EVAR, Figure 4[33]



Ultrasonography of EVAR, Figure 5[32]

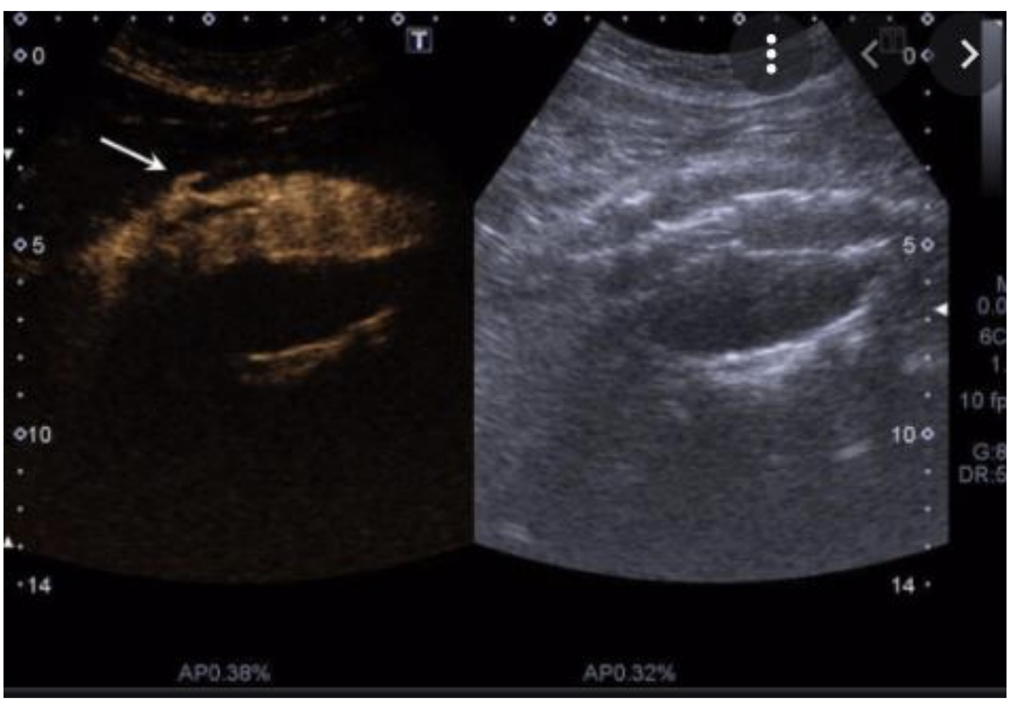


Table 2 31

Table 2 Advantages and disadvantages of CT/CTA

Advantages	
	Highly reproductive
	Not dependent on patients body weigh
	Faster picture analysis
Disadvantages	
	Contrast agent nephrotoxicity
	High cost
	Radiation
	False negative or endotension

Abbreviations: CT, computed tomography; CTA, computed tomography angiography.

Table 3 31

Table 3 Advantages and disadvantages of CDU

Advantages
Low cost
Portable
Static and Dynamic information
Disadvantages
Examiner dependent
Longer time of examination
Dependent on patient body
Dependent on patient body habitus
Dependent on the quality of the equipment

Abbreviation: CDU, color duplex ultrasound.

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