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Endovascular Aneurysm Repair Increases Aortic Arterial Stiffness When Compared to Open Repair of Abdominal Aortic Aneurysms

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Abstract

Objectives: The initial survival advantage seen with endovascular aneurysm repair (EVAR) over open repair does not persist in the long term. Pulse wave velocity (PWV) is a measure of arterial stiffness, and increased PWV is an independent risk factor for increased cardiovascular morbidity and mortality. This prospective comparative pilot study examined the effect of implantation of an aortic graft on PWV in patients undergoing open or endovascular aortic aneurysm repair. **Patients and Methods:** Thirty-four patients (15 open and 19 EVAR) were recruited. Patient demographics were similar in both the groups. Pulse wave velocity was calculated for all patients preoperatively and postoperatively using a standardized technique on a Philips IU22 Vascular Ultrasound machine and the results compared. **Results:** An increase in mean PWV following EVAR was demonstrated. The mean postprocedure PWV of 9.7 ($\pm$ 4.5) cm/sec detected in the open group was significantly lower than the elevated 12.2 ($\pm$ 4.5) cm/sec detected in the EVAR group. The surgical group also demonstrated a mean decrease of 0.2 ($\pm$ 4.9) cm/sec in PWV following open repair compared to a mean increase of 3.3 ($\pm$ 3.7) cm/sec in the EVAR group. **Conclusion:** EVAR patients have a significantly higher postoperative PWV measurement than those undergoing open abdominal aortic aneurysm repair. Patients who have undergone EVAR may be at a higher risk of cardiovascular morbidity in the long term. A larger scale study with a longer prospective follow-up is required.

Keywords

pulse wave velocity, endovascular aneurysm repair, abdominal aortic aneurysm, open aneurysm repair

Introduction

Endovascular aneurysm repair (EVAR) reduces the 30-day mortality rate by two-thirds compared to open repair, but this advantage does not persist, with similar long-term survival rates being reported for both the procedures.[1-4] This may be because the more minor surgical insult associated with EVAR is only beneficial during the perioperative period or alternatively because endograft implantation carries with it a unique complication that neutralizes the beneficial effect of the lesser surgical insult experienced during repair.

Cardiac complications are the principal sources of late morbidity and mortality following abdominal aortic aneurysm (AAA) repair.[5,6] We sought to determine whether implantation of an endovascular aortic graft potentially increased cardiovascular risk, thus offering an explanation why the initial survival advantage seen with EVAR over open repair does not persist.

Pulse wave velocity (PWV) is a measure of arterial stiffness, and an increase in PWV is an independent risk factor for increased cardiovascular morbidity and mortality.[7] Aortic PWV is an indicator of the stiffness of large arteries and is an independent predictor of morbidity and mortality, especially in the elderly population.[7] The PWV is the time taken for the arterial pulse to propagate from the common carotid artery (CCA) to either the radial or the femoral artery.

Increased PWV is associated with the outcomes of patients with other atherosclerotic disorders. However, there is little to support a link between elevated PWV and the outcome of patients post-EVAR. Despite the improvement in 30-day mortality associated with EVAR, adverse cardiac events are still

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the leading cause of long-term mortality following AAA repair.[8]

There have been several large randomized trials to date which demonstrate an improved 30-day survival rate for EVAR versus the open aneurysm repair but no difference in the quality of life at 1 year. All-cause mortality rates were similar between the open group and EVAR group at 4 years, suggesting that the initial survival benefit associated with the reduction in perioperative mortality does not persist.[1-3] Others have demonstrated that the major adverse events affecting long-term morbidity and mortality following EVAR were cardiac in origin.[6]

The aim of this pilot study was to examine the effect of AAA repair on PWV in both open and endovascular repair in the short term postoperatively.

Patients and Methods

Following approval from the local ethics committee, 34 patients undergoing elective infrarenal AAA repair between July 2008 and June 2010 consented to participate in the study and had their PWV calculated prior to and following the surgery. Consecutive patients in this time period were selected for EVAR or open repair according to anatomical criteria based on the preoperative computerized tomographic scan. Patients with concombinant occlusive disease were excluded to avoid contamination of PWV results. Patients with suprarenal aortic disease which would require more complex open or endovascular surgery were also excluded.

The EVAR stent grafts were all bifurcated and positioned immediately distal to the lowest renal artery and used suprarenal fixation barbs. Distally, the iliac limbs were positioned just proximal to the iliac bifurcations. The open aneurysm repairs were performed via a transperitoneal approach, with the proximal anastomosis immediately below the renal arteries and a straight Dacron graft Dacron (Vascutek, Inchinnan, Renfrewshire, Scotland, UK) sewn distally at the aortic bifurcation, in the standard approach. Although a bifurcated graft for open repair may have given a better comparison for the study, the lack of iliac disease in these patients meant it could not be clinically justified. Follow-up of EVAR patients was by standard local protocol, while open repair patients were discharged within 6 months if clinically well.Pulse wave velocity was calculated by a previously validated method.[9,10] All patients rested supine for approximately 10 minutes prior to being scanned by the same accredited vascular technologist (CG) in a darkened temperature-controlled room using a Philips IU22 Vascular Ultrasound (Leopardstown, Dublin 18, Ireland) system with a 7- to 10-MHz linear array transducer. The 2 reference points used were the right common carotid and common femoral arteries.[9] The path length (the distance between the sternal notch and the femoral arteries) was measured using a standard commercially available tape measure. A duplex image of the right CCA proximal to the bifurcation was obtained in a longitudinal plane. The Doppler spectral waveform and electrocardiogram (ECG) trace were then recorded simultaneously for several cycles, and the time interval between the R waves of the ECG to the foot of the Doppler waveform was determined using the on-board computer and callipers. The foot of the waveform was identified by the intersection of the upstroke of the wave with the baseline of the zero frequency (Figure 1). This procedure was then repeated on the right common femoral artery. The PWV was then calculated using the previously described equation, where the length is divided by the pulse transit time of carotid to femoral (Figure 2).[11] The PWV was then recalculated 4 weeks postoperatively using the same methodology. The method is summarized schematically in Figure 3.

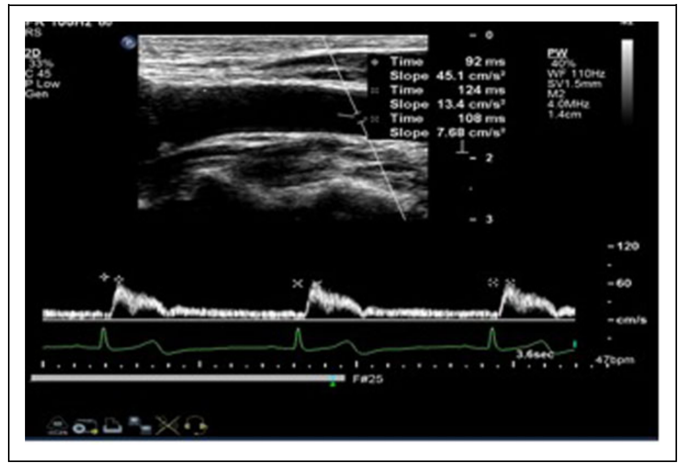

Figure 1. Measurement of the time interval between the R-wave of an ECG trace and the foot of the Doppler waveform in the right CCA. ECG indicates electrocardiogram; CCA, common carotid artery.

Figure 2. Measurement of the time interval between the R-wave of an ECG trace and the foot of the Doppler waveform in the right CFA. ECG indicates electrocardiogram; CFA, common femoral artery.

A power calculation was not performed, due to a lack of any similar previous studies, and the present study was designed as a pilot study. Continuous variables were expressed as mean ($\pm$ standard deviation [SD]) and proportions as percentages. Student *t* test and Fisher Exact test were used to compare groups using statistical analysis system software. A P value of $< .05$ was considered statistically significant.

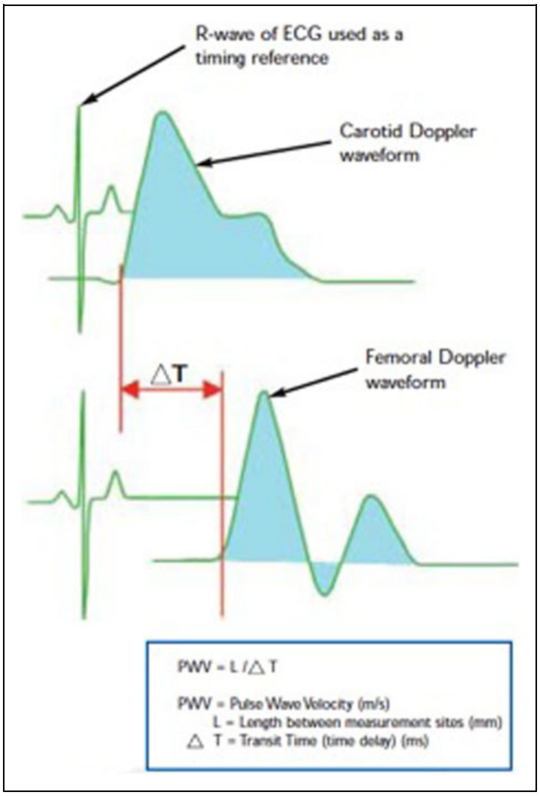

Figure 3. Measurement of PWV using the R-wave of the ECG trace as a timing reference. PWV indicates pulse wave velocity; ECG, electrocardiogram.

Results

Patient Demographics

There were 31 (90%) male and 3 (10%) female patients with an overall mean (± SD) age of 73 (± 6.8) years. Fifteen (44.1%) patients underwent open surgical repair with a mean age of 72 (± 7.7) years, and 19 (55.8%) patients underwent EVAR with a mean age of 73 (± 6.2) years. Patient demographics and comorbidities in the 2 groups are detailed in Table 1. Due to low patient numbers, any significance reached in these comparisons may not be robust. In order to minimize intergraft variability, all EVAR patients had a Cook (William Cook Europe, Bjaeverskov, Denmark) stent graft used.

Preoperative PWV

Mean PWV for the entire group of 34 patients prior to undergoing intervention was found to be 9.3 (± 2.6) m/sec. Mean PWV in the open group was 9.9 (± 3.1) m/sec and 8.8 (± 2.1) m/sec in the EVAR group (P = .43).

Open Surgical Repair Group (n = 15)

Mean PWV was 9.9 (± 3.1) m/sec prior to surgery and 9.7 (± 4.5) m/sec postoperatively. The mean change was found to be a nonsignificant change of 0.2 (± 4.9) m/sec (P = .8).

Table 1. Risk Factor Profile of Patients Within Each Group.

Risk Factor	EVAR patients (%), n = 19	Open Repair Patients (%), n = 15
Male	84.2	100
Female	15.8	0
Smoking history	35.3	40
Diabetes	23.5	6.6
Hypertension	41.2	46.6
Hypercholesterolemia	52.9	20.0
Coronary artery disease	52.9	13.3
Family history of AAA	11.7	6.6
Aspirin	47.0	53.3
Lipitor	29.4	13.3
Clopidogrel	11.7	13.3
Warfarin	0	6.6

Abbreviations: EVAR, endovascular aneurysm repair; AAA, abdominal aortic aneurysm.

Endovascular Aneurysm Repair Group (n = 19)

Mean PWV increased from 8.8 (± 2.1) m/sec to 12.2 (± 4.5) m/sec following endograft implantation. The mean change in PWV was a significant increase of 3.3 (± 3.7) m/sec (P = .001).

Postoperative PWV

Postoperative PWV was significantly elevated in the EVAR group at 12.2 (± 4.5) m/sec compared to those who had undergone open repair, 9.7 (± 4.5) m/sec (P = .001).

Postoperative Outcome and 5-Year Survival

In the EVAR group of patients, there were 5 complications. Two patients required iliac branch extensions for subsequent type 1B endoleaks; 1 patient developed a urinary tract infection, while another developed diverticulitis resulting in a laparotomy; the fifth patient had bleeding from the groin puncture sight which ultimately required an interposition graft due to the poor quality of the femoral artery.

In the open aneurysm repair group, 3 patients had a complication. One had renal insufficiency, while another had renal insufficiency as well as pneumonia. Both patients recovered without need for dialysis. The third patient had a mild coronary infarct, which necessitated a coronary angiogram, but made a full recovery.

Eleven of the 19 patients who underwent EVAR had died within the first 5 years of follow-up. Only 3 of the 15 patients who underwent open aneurysm repair had died within the same time period (P = .038). Unfortunately, the cause of death could not be obtained for most, so the aneurysm-related, or cardiovascular-specific, death rates could not be calculated, in addition to the overall survival above.

Discussion

The finding that the initial perioperative survival advantage seen with EVAR over open AAA repair did not persist in the long term surprised many and has led to several hypotheses as to why this is so. In the EVAR 1 trial, secondary rupture after aneurysm repair was reported only after EVAR and appeared to explain the long-term increase in aneurysm-related mortality.[4] However, the same trial reported more cardiovascular deaths in the EVAR group, leading the authors to speculate that this contributed to the convergence in all-cause mortality during the first 2 years.[12]

We sought to examine whether the lesser surgical insult of EVAR was offset by an increase in long-term cardiovascular risk due to the different aortic prosthesis used. We hypothesized that the implantation of a rigid endograft could alter aortic compliance, thus impacting on cardiac morbidity. The PWV has prognostic value in unreconstructed state, reflecting the diseased vascular system. Carotid–femoral PWV is a recognizable index of aortic stiffness and has been proven to be an important predictor of cardiovascular events.[8]

This pilot study demonstrated a significant increase in mean PWV in patients undergoing EVAR compared to open AAA repair. The PWV, in other contexts, is an independent predictor of cardiovascular morbidity and mortality, with age, hypertension, renal failure, and diabetes being the primary determinants of arterial stiffness.[7,8,13] Although this study provides short-term information on PWV only, it could be hypothesized that the nature of intervention modifies this outcome predictor. Other factors that may influence the group differences include increased inflammatory response and more adverse anatomical selection criteria for the open repair group. However, both of these factors run contrary to the present results, suggesting that they do not play a significant role.

Although the 2 groups were similar in terms of risk factor variables, limitations to this study must be acknowledged, in particular gender distribution and sample size. There were only 3 (15.8%) female patients in the EVAR group and none in the open repair cohort. As gender can affect PWV, this needs to be addressed with a larger study containing a more evenly distributed population. There are a few other weaknesses to be acknowledged. First, the effect of intervention on hypertension control was not assessed and should be included in a future study of this kind, since aortic stiffness and hypertension are related. Second, it may be interesting to use 2 measurements for PWV, where the second is defined as from CCA to radial artery, thus excluding any direct effect of the aortic stent graft. Third, all cardiovascular studies have a large potential number of variables and risk factors. Only a few major ones were assessed in this study, and it would be essential to expand the number of possible factors and confounders in future studies, including a more comprehensive pharmacological analysis.

Conclusion

Implantation of an aortic endograft increases arterial stiffness, which may have long-term effects on cardiovascular morbidity in patients undergoing EVAR and could explain the lack of long-term survival advantage seen in this population. This is confirmed by the survival difference between the 2 groups after 5 years, but a larger scale study with a longer prospective follow-up is needed to pursue these findings.

Declaration of Conflicting Interests

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