Open Abdominal Aortic Aneurysm Repair in the Era of Endovascular Repair

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ABSTRACT

Objectives: *The development of minimally invasive techniques for abdominal aortic aneurysm (AAA) repair and the establishment of specialized centres have resulted in improved patient outcomes. This study examines open AAA repair at a non-specialized centre where advanced techniques are not practised.*

Methods: *We conducted a retrospective analysis on a cohort of 83 patients presenting for AAA repair to a non-specialized hospital, the University Hospital of the West Indies (UHWI). The end points assessed included operative (30-day) mortality, postoperative complications, duration of operation, blood loss, intensive care unit (ICU) stay and overall hospital stay.*

Results: *The overall operative mortality was 9.4% (23% for ruptured aneurysms and 5% for unruptured aneurysms). Mean operating time, blood loss, ICU stay and hospital stay were 326 ± 98 minutes, 2420 ± 1397 mls, 3 ± 5 days and 9 ± 5 days, respectively with no significant differences noted between ruptured and unruptured aneurysms. Mean aneurysm diameter was 6.13 ± 1.59 cm.*

Conclusion: *Mortality rates for open aneurysm repair at the UHWI are consistent with findings in the current literature. Open AAA repair remains a safe treatment option in this environment. Continued improvements need to be made with respect to minimizing blood loss and operation duration, particularly in repairs of unruptured aneurysms.*

Keywords: Abdominal, aneurysm, aorta, repair

Reparación Abierta de la Aorta Abdominal en la Era de la Reparación Endovascular

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RESUMEN

Objetivos: *El desarrollo de técnicas mínimamente invasivas para la reparación del aneurisma aórtico abdominal (AAA) y el establecimiento de centros especializados para esos fines, han traído consigo el mejoramiento de los resultados clínicos de los pacientes. Este estudio examina reparaciones del tipo AAA en un centro no especializado, en el que no se practican técnicas avanzadas.*

Métodos: *Se llevo a cabo un análisis retrospectivo en una cohorte de 83 pacientes que acudieron para reparación de AAA a un hospital no especializado – el Hospital Universitario de West Indies (UHWI). Los aspectos finales evaluados incluyeron la mortalidad operatoria (30 días), las complicaciones post-operatorias, la duración de la operación, la pérdida de sangre, la estadía en la unidad de cuidados intensivos, y la estadía general en el hospital.*

Resultados: *La mortalidad operatoria general fue 9.4% (23% para los aneurismas rotos y 5% para los aneurismas no rotos). El tiempo promedio de operación, la pérdida de sangre, la estadía en la UCI, y la estadía hospitalaria fueron 326 ± 98 minutos, 2420 ± 1397 mls, 3 ± 5 días y 9 ± 5 días respectivamente, sin que se observen diferencias significativas entere aneurismas rotos y no rotos. El diámetro promedio de los aneurismas fue 6.13 ± 1.59 cm.*

Conclusión: *Las tasas de mortalidad para la reparación abierta de aneurismas en el UHWI concuerdan con los hallazgos en la literatura corriente. Se necesita continuar los esfuerzos por lograr*

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mejorías en cuanto a minimizar la pérdida de sangre, y reducir el tiempo de duración de la operación, especialmente en las reparaciones de aneurismas no rotos.

Palabras claves: abdominal, aneurisma, aorta, reparación

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INTRODUCTION

Abdominal aortic aneurysm (AAA) repair is a major surgical procedure with potential significant morbidity and mortality. It has been suggested that AAA repairs performed by specialized surgeons and in institutions of high volume have better outcomes (1). The advent of endovascular repair (EVAR) has also resulted in improved short-term outcomes (2). At this point, specialized centres are not available in the Caribbean and EVAR is not readily accessible. For these reasons, open aneurysmorrhaphy performed by general surgeons remains the mainstay of treatment for AAAs in the Caribbean.

Operative mortality rates for ruptured AAAs remain high (48%) despite improvements in prehospital and emergency room care (3). The early identification, close surveillance and early management of patients with unruptured AAAs have resulted in reduced operative mortality rates of 5.5% in asymptomatic patients (4) and up to 19% for symptomatic cases (5). Despite significant improvement in 30-day operative mortality [1.2% (6); 1.8% (7)] and some benefits conferred to patients not fit for open repair (8), long-term results for EVAR suggest greater morbidity and cost (7). As such, open repair remains a durable treatment option.

Reasonable outcomes for AAA repair can still be achieved by general surgeons at non-specialized centres. Thirty-day mortality rates for elective AAA repairs, in this setting, have been quoted at 5% (9) and 7.75% (10). The University Hospital of the West Indies (UHWI) is a tertiary level centre in a developing country. We hypothesize that open repair remains a safe treatment option for patients with AAA in our region.

SUBJECTS AND METHODS

Following approval by The University of the West Indies Ethics Committee, a retrospective analysis of all patients presenting for elective or emergency AAA surgery at the UHWI during the period January 1990 to December 2008 was conducted. Records were identified using the operative database and the coded patient files from the medical records department. Patients diagnosed with thoraco-abdominal aortic aneurysms were excluded. For the purposes of comparison, the cohort was divided into ruptured and unruptured cases. Records were identified for eighty-three patients who form the basis of the study. Data were extracted and analysed using version 17 of the Statistical Package for the Social Sciences (SPSS). *T*-test analysis was used to compare outcome measures for ruptured and unruptured AAAs. A p-value < 0.05 was considered significant.

RESULTS

During the 18-year period between January 1990 and December 2008, 199 patients presenting to the surgical service at the UHWI were coded as having an 'aneurysm'. Records for 109 of these patients were available. Of these, 83 patients fulfilled the inclusion criteria. The peak age of included patients was in the 70–79-year age group (Table 1), with a male predominance of 2.1 to 1. Sixty-four per cent of patients were symptomatic on presentation. Abdominal pain was the commonest presenting symptom (67.9%), followed by back pain (30.2%). Symptoms for ruptured and unruptured AAAs were similar (Table 2). Pre-existing coronary artery disease, defined as angina pectoris, previous myocardial infarction or electrocardiogram (ECG) evidence of ischaemia, was documented in 16 cases. Hypertension (systolic greater than 140 mmHg and/or diastolic greater than 100 mmHg) was seen in 57 cases. Pulmonary disease and prior transient ischaemic attack/stroke were noted in 11 and 7 patients respectively.

Table 1: Distribution of patients with abdominal aortic aneurysm, by age

Age range	Percentage of patients (number)
40–49	1.2 (1)
50–59	7.2 (6)
60–69	31.3 (26)
70–79	39.8 (33)
80–89	19.3 (16)
90–99	1.2 (1)

Table 2: Symptomatology of abdominal aortic aneurysm, by rupture status

	Percentage of ruptured cases (number)	Percentage of unruptured cases (number)
Abdominal pain	73.9 (17)	63.3 (19)
Back pain	21.7 (5)	36.7 (11)
Claudication	0 (0)	6.7 (2)
Chest pain	4.3 (1)	3.3 (1)
Acute limb ischaemia	4.3 (1)	3.3 (1)
Gastrointestinal bleed	4.3 (1)	0 (0)
Syncope	4.3 (1)	0 (0)
Erectile dysfunction	4.3 (1)	0 (0)
Hip pain	4.3 (1)	0 (0)

The majority of AAAs (92.8%) were infrarenal. The mean diameter based on ultrasound or computed tomography

(CT) examinations was 6.13 ± 1.59 cm (range: 3 to 10.5 cm). Of note, 48% of the AAAs measured less than 6 cm while only one AAA exceeded 10 cm in diameter. Sixty-five per cent of the patients presenting to the unit had surgery. The commonest reasons for non-resection were refusal of surgery and general poor condition of the patient (Table 3). Elective

Table 3: Reasons for nonresection

Reason for nonresection	Percentage of patients (number)
Refused surgery	44.83 (13)
Poor risk based on medical condition	17.24 (5)
Surgery not indicated	13.79 (4)
Family wished overseas care	6.90 (2)
No ICU space available	6.90 (2)
Intra-operative instability	3.45 (1)
No blood available	3.45 (1)
Death prior to intervention	3.45 (1)

operations were performed twice as frequently as emergency operations. Mean operating time was 326 ± 98 minutes (range: 135 – 600 minutes) with a mean aortic clamp time of 119 ± 48 minutes (range: 41 – 246 minutes). Mean blood loss was 2420 ± 1397 mls. Patients were admitted to the intensive care unit (ICU) for an average of 3 ± 5 days with an overall average hospital stay of 9 ± 5 days.

T-test analysis showed no difference between ruptured and unruptured AAAs with respect to duration of procedure, aortic clamp time, blood loss or length of ICU stay (Table 4).

Table 4: Comparison of ruptured and unruptured aneurysms with respect to outcome measures

	Ruptured or unruptured	Mean	Std. Deviation	*p*-value
Blood loss (mls)	ruptured	2400.00	1492.202	
	unruptured	2419.33	1392.539	0.965
Duration (mins)	ruptured	329.69	100.041	
	unruptured	331.06	94.681	0.963
Aortic clamp time (mins)	ruptured	114.69	52.927	
	unruptured	120.57	45.946	0.715
ICU stay (days)	ruptured	1.93	1.438	
	unruptured	3.79	5.788	0.228

There were too few deaths to establish an association between operative factors, patient characteristics and mortality. Overall hospital mortality (death prior to discharge or within 30 days of the operation) was 9.4% for the cohort of resected cases. In the 13 cases of confirmed rupture, mortality for resection was 23% (3 cases). Resection of unruptured AAAs, whether operated on electively or as an emergency for suspected rupture, carried a mortality of 5%. The causes of death involved exsanguination in three cases (postoperatively in two), and cardiac arrest in the remaining two cases. Thirty per cent of patients had some form of postoperative complication (Table 5). Only one patient developed a graft-specific complication, that of graft occlusion requiring re-anastomosis and embolectomy.

Table 5: Postoperative complications

Complication	Number of cases
Adhesive bowel obstruction	1
Ileus	1
Renal infarction	1
Graft thrombosis	2
Cardiac failure	3
Lower limb ischaemia due to arterial occlusion	2
Pneumonia	4
Deep vein thrombosis and pulmonary embolism	3
Infected graft seromas	1

The retroperitoneal approach to the aneurysmorrhaphy was used in five cases. The remainder were approached transabdominally. Fifty-seven per cent of patients undergoing elective surgery had epidural-based anaesthesia. Intra-operative blood transfusions were required in 45 (83.3%) patients at a mean volume of 890 millilitres (mls). Autologous blood transfusion was used in 12 cases.

DISCUSSION

With the developments of EVAR (11) and laparoscopic AAA repair (12), the use of open AAA repair at specialized centres is likely to lessen significantly. Still, it remains the mainstay of treatment in non-specialized centres (10). With the push for regionalization of certain procedures to centres of high volume (13), validation of acceptable outcome measures at these non-specialized centres becomes necessary. This is particularly relevant in the Caribbean where regionalization is not imminent.

The present study shows the mean diameter of AAA presenting for repair to be 6.13 ± 1.59 cm. Almost 16% of the cohort refused surgery. For those who had AAA repair, overall operative mortality rate was 9.4%, mortality rate for ruptured aneurysms was 23% and that for unruptured aneurysms was 5%.

A study similar to the present one was conducted by Branday *et al* in 1983 at the UHWI (14). It evaluated 101 patients over an 18-year period (1965–1982). Though the methodology differed, comparison of the outcomes showed considerable improvements in overall mortality rates [9.4% *vs* 25% (14)] and mortality rates for unruptured [5% *vs* 16% (14)] and ruptured AAAs [23% *vs* 53% (14)]. The present study was unable to link mortality to patient and aneurysm factors due to the low number of deaths. Symptomatology remained similar with abdominal pain and back pain being the predominant complaints in both articles. This study shows a trend towards operating on smaller aneurysms, the use of epidural anaesthesia, the retroperitoneal approach to AAA repair and the use of autologous blood transfusion.

The literature on AAA repair in the community is limited. Studies show mortality rates for elective repair in non-specialized centres ranging from 5.1% (15) to 7.75%

(10). Yii found a 6% mortality rate for elective repair in their population undergoing repair in a developing country (9). Though these mortality rates are higher than those noted in some large multicentre studies (7, 8), they have been found to be similar to rates from other published series of open repair (16, 17). The mortality rate for unruptured AAAs in our study of 5% is consistent with the present literature for repairs in the community. The improvement in mortality rate at UHWI could be attributed to improvements in peri-operative care – preoperative optimization of patients, intra-operative monitoring and cardiovascular support and improved postoperative ICU support. This has been supported by other authors (18). Low surgeon volume and operative experience have been found to contribute to operative mortality (19). This is a relevant concern at our institution. Further improvements in operative mortality may come with the creation of dedicated teams of surgeons, anaesthetists and intensivists. As EVAR is unlikely to be introduced at UHWI in the near future and most patients unlikely to afford care in overseas specialized centres, it is incumbent that attention be directed to the optimization of the above factors to further reduce morbidity and mortality.

Unlike elective AAA repair, mortality rates for ruptured AAAs remain consistently high despite improvements in prehospital emergency care, surgical technique and postoperative management of complications. The mortality rate of 23% in the present study appears to be lower than other documented rates (20, 21). This has to be interpreted cautiously, however, in the face of low patient numbers. A meta-analysis of 50 years of ruptured AAA repair noted that though mortality rates have reduced over time, the overall operative mortality rate still remains high at 48% (3). Factors out of the control of the surgeon such as excess blood loss and blood administration, excess fluid administration and intra-operative cardiac arrest have been implicated in these poor outcomes (22─24). It has been suggested that the use of EVAR for ruptured AAAs can lead to reduction in mortality rates (25), with reports quoting figures of 8% (26) to 22.2% (27). Though this technique shows promise, it must be seen with caution until stronger supportive evidence is established (28).

Thirty-five per cent of patients in the present study presenting for AAA repair did not undergo resection. This proportion is high compared to other series that suggested poor surgical risk and the presence of a stable aneurysm as the predominant reasons for non-resection (29). Refusal to undergo surgery represented the majority of cases of non-resection in our series (15.7% of cohort). A similar finding was noted in a Chinese series published by Wei *et al* (30). Ethnic and cultural beliefs may contribute to this refusal of care. In addition, while obtaining informed consent for surgery, the discussion with patients about the previously published high mortality rates (14) may have led to fear and further contributed to refusal of care.

Blood loss during an AAA repair (14, 31, 32), operative time (14, 32) and aortic clamp time (14, 32, 33) are factors contributing to early mortality after AAA repair. Though our analysis was unable to determine predictors of mortality, no difference was found between ruptured and unruptured AAAs with respect to these factors. Overall results are more consistent with the literature on ruptured (21, 32) rather than unruptured AAAs. Bearing in mind the recognized association between these factors and mortality, continued efforts to improve them in the elective/semi-elective setting must be made. This includes continued multidisciplinary care, improvements in comorbidity optimization and infrastructure development (ICU beds, nursing staff, monitoring equipment).

Clear areas of evolution were demonstrated with the use of epidural anaesthesia and autologous blood transfusion. The use of epidural anaesthesia/analgesia is a component of 'fast track' AAA repair and contributes to a reduction in postoperative ventilation, morbidity and overall hospital stay (34). Autologous blood transfusion [acute normovolaemic haemodilution (ANH) and intra-operative red cell salvage (IBS)] is noted to reduce adverse outcomes such as systemic inflammatory response syndrome (SIRS) and infectious complications related to AAA repair (35). It also reduces the requirements for allogeneic blood transfusion (36, 37) which benefits circumstances of allogeneic blood shortages (38). This is a problem often faced in developing countries.

The present study shows that AAA repair can be performed with reasonable outcomes in regions lacking specialized vascular centres or minimally invasive vascular techniques. The results of the study must be taken into context, however. The power of the study is limited by its retrospective nature and the amount of data available for analysis. This may limit the generalizability of the results. Further prospective evaluation of open AAA repair in this setting would be useful in supporting the results of this study while following the progress in the use of supportive adjuncts such as epidural anaesthesia and autologous blood transfusion. In addition, with the lack of availability of and access to EVAR, the future development of specialized teams will undoubtedly continue to improve the care administered.

REFERENCES

1. Dimick JB, Cowan JA Jr, Stanley JC, Henke PK, Pronovost PJ, Upchurch GR Jr. Surgeon specialty and provider volumes are related to outcome of intact abdominal aortic aneurysm repair in the United States. J Vasc Surg 2003; **38:** 739–44.
2. Lovegrove RE, Javid M, Magee TR, Galland RB. A meta-analysis of 21 178 patients undergoing open or endovascular repair of abdominal aortic aneurysm. Br J Surg 2008; **95:** 677–84.
3. Bown MJ, Sutton AJ, Bell PRF, Sayers RD. A meta-analysis of 50 years of ruptured abdominal aortic aneurysm repair. Br J Surg 2002; **89:** 714–30.
4. Hallin A, Berqvist D, Holmberg L. Literature review of surgical management of abdominal aortic aneurysm. Eur J Vasc Endovasc Surg 2001; **22:** 197–04.

5. Haug ES, Romundstad PP, Aadahl P, Myhre HO. Emergency non-ruptured abdominal aortic aneurysm. Eur J Vasc Endovasc Surg 2004; **28:** 612–8.
6. Prinssen M, Verhoeven EL, Buth J, Cuypers PW, van Sambeek MR, Balm R et al. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med 2004; **351:** 1607–18.
7. United Kingdom EVAR Trial Investigators, Greenhalgh RM, Brown LC, Powell JT, Thompson SG, Epstein D et al. Endovascular versus open repair of abdominal aortic aneurysm. N Engl J Med 2010; **362:** 1863–71. Epub 2010 Apr 11.
8. United Kingdom EVAR Trial Investigators, 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. Epub 2010 Apr 11.
9. Yii MK. Initial experience of abdominal aortic aneurysm repairs in Borneo. ANZ J Surg 2003; **73:** 790–3.
10. Qureshi NA, Rehman A, Slater N, Moss E, Shiralkar S, Patel RT et al. Abdominal Aortic Aneurysm Surgery in a District General Hospital: A 15-Years Experience. Ann Vasc Surg 2007; **21:** 749–53.
11. Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal gradt implantation for abdominal aortic aneurysms. Ann Vasc Surg 1991; **5:** 491–9.
12. Edoga JK, Asgarian K, Singh D, James KV, Romanelli J, Merchant S et al. Laparoscopic surgery for abdominal aortic aneurysms. Technical elements of the procedure and a preliminary report of the first 22 patients. Surg Endosc 1998; **12:** 1064–72.
13. Hill JS, McPhee JT, Messina LM, Ciocca RG, Eslami MH. Regionalization of abdominal aortic aneurysm repair: evidence of a shift to high-volume centers in endovascular era. J Vasc Surg 2008; **48:** 29–36.
14. Branday JM, Fletcher PR, DuQuesnay DR, Rao AB, Raje D. Abdominal Aortic Aneurysms: Results of Resection. West Indian Med J 1983; **32:** 232–36.
15. El Kafsi J, Wake J, Lintott P, Northeast A, McLaren A. Three-year audit and cost assessment of open abdominal aortic aneurysm repair in a district general hospital. Ann R Coll Surg Engl 2009; **91:** 645–8.
16. Hadjianastassiou VG, Tekkis PP, Goldhill DR, Hands LJ. Quantification of mortality risk after abdominal aortic aneurysm repair. Br J Surg 2005; **92:** 1092–8.
17. Sayers RD, Thompson MM, Nasim A, Healey P, Taub N, Bell PR. Surgical management of 671 abdominal aortic aneurysms: a 13-year review from a single centre. Eur J Vasc Endovasc Surg 1997; **12:** 322–7.
18. Berge C, Haug ES, Romundstad PR, Lange C, Myhre HO. Improved long-term survival following infrarenal abdominal aortic aneurysm repair. Scand Cardiovasc J 2008; **42:** 354–9.
19. Dardik A, Lin JW, Gordon TA, Williams GM, Perler BA. Results of elective abdominal aortic aneurysm repair in the 1990s: A population-based analysis of 2335 cases. J Vasc Surg 1999; **30:** 985–95.
20. Hatori N, Yoshizu H, Shimizu M, Hinokiyama K, Takeshima S, Kimura T et al. Prognostic factors in the surgical treatment of ruptured abdominal aortic aneurysms. Surg Today 2000; **30:** 785–90.
21. Bhuyan RR, Sadiq A, Theodore S, Neelakandhan KS, Unnikrishnan M, Karunakaran J. Outcomes of surgical management of ruptured abdominal aortic aneurysm. Ind Thorac Cardiovasc Surg 2006; **22:** 132–6.
22. Wakefield TW, Whitehouse WM Jr, Wu SC, Zelenock GB, Cronenwett JL, Erlandson EE et al. Abdominal aortic aneurysm rupture: statistical analysis of factors affecting outcome of surgical treatment. Surgery 1982; **91:** 586–96.
23. Donaldson MC, Rosenberg JM, Bucknam CA. Factors affecting survival after ruptured abdominal aortic aneurysm. J Vasc Surg 1985; **2:** 564–70.
24. Harris LM, Faggioli GL, Fiedler R, Curl GR, Ricotta JJ. Ruptured abdominal aortic aneurysms: factors affecting mortality rates. J Vasc Surg 1991; **14:** 812–8.
25. Morasch MD. EVAR for the treatment of ruptured AAA. Perspect Vasc Surg Endovasc Ther 2009; **21:** 9–11.
26. Brandt M, Walluscheck KP, Jahnke T, Graw K, Cremer J, Müller-Hülsbeck S. Endovascular repair of ruptured abdominal aortic aneurysm: feasibility and impact on early outcome. J Vasc Interv Radiol 2005; **16:** 1309–12.
27. Davenport DL, O'Keeffe SD, Minion DJ, Sorial EE, Endean ED, Xenos ES. Thirty-day NSQIP database outcomes of open versus endoluminal repair of ruptured abdominal aortic aneurysms. J Vasc Surg 2010; **51:** 305–9.
28. Rayt HS, Sutton AJ, London NJ, Sayers RD, Bown MJ. A systematic review and meta-analysis of endovascular repair (EVAR) for ruptured abdominal aortic aneurysm. Eur J Vasc Endovasc Surg 2008; **36:** 536–44.
29. Vohra R, Reid D, Groome J, Abdool-Carrim AT, Pollock JG. Long-term survival in patients undergoing resection of abdominal aortic aneurysm. Ann Vasc Surg 1990; **4:** 460–5.
30. Wei WI, Siu KF, Wong J. Abdominal aortic aneurysm in Chinese patients. Br J Surg 1995; **72:** 900–2.
31. Urbonavicius S, Vorum H, Urbonaviciene G, Trumpickas M, Pavalkis D, Honoré B. Predictors of post-operative mortality following treatment for non-ruptured abdominal aortic aneurysm. Curr Control Trials Cardiovasc Med 2005; **6:** 14.
32. Davidović L, Marković M, Kostić D, Cinara I, Marković D, Maksimović Z et al. Ruptured abdominal aortic aneurysms: factors influencing early survival. Ann Vasc Surg 2005; **19:** 29–34.
33. MacKenzie S, Swan JR, D'Este C, Spigelman AD. Elective open abdominal aortic aneurysm repair: a seven-year experience. Ther Clin Risk Manag 2005; **1:** 27–31.
34. Meuhling BM, Halter G, Lang G, Schelzig H, Steffen P, Wagner F et al. Prospective randomized controlled trial to evaluate "fast-track" elective open infrarenal aneurysm repair. Langenbecks Arch Surg 2008; **393:** 281–7.
35. Mercer KG, Spark JI, Berridge DC, Kent PJ, Scott DJ. Randomized clinical trial of intra-operative autotransfusion in surgery for abdominal aortic aneurysm. Br J Surg 2004; **91:** 1443–8.
36. Szalay D, Wong D, Lindsay T. Impact of red cell salvage on transfusion requirements during elective abdominal aortic aneurysm repair. Ann Vasc Surg 1999; **13:** 576–81.
37. Wong JC, Torella F, Haynes SL, Dalrymple K, Mortimer AJ, McCollum CN; ATIS Investigators. Autologous versus allogeneic transfusion in aortic surgery: a multicenter randomized clinical trial. Ann Surg 2002; **235:** 145–51.
38. Healy CF, Doyle M, Egan B, Hendrick B, O'Malley MK, O'Donohoe MK. Transfusion requirements and outcomes in patients undergoing abdominal aortic surgery using intra-operative cell salvage. Ir J Med Sci 2007; **176:** 33–6.