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Repair of Ruptured Abdominal Aortic Aneurysm in Octogenarians

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Abstract *Objective:* To determine whether advanced age was independently associated with prohibitive surgical risks or impaired long-term prognosis after ruptured aortic aneurysm repair.
Design: Post-hoc analysis of prospective cohort.
Materials: Consecutive patients undergoing ruptured aneurysm repair between January 2001 and December 2010 at a tertiary referral centre.
Methods: Surgical mortality (i.e., <30 days) was compared between octogenarians and younger patients using logistic regression modelling to adjust for suspected confounders and to identify prognostic factors. Long-term survival was compared with matched national populations.
Results: Sixty of 248 involved patients were octogenarians (24%) and almost all were offered open repair ($n = 237$). Surgical mortality of octogenarians was 26.7% (adjusted odds ratio (OR) 2.1; 95% confidence interval (CI), 0.9—5.2) and confounded by cardiac disease. Hypovolaemic shock predicted perioperative death of octogenarians best (OR 5.1; 95%CI, 1.1—23.4; $P = 0.037$). After successful repair, annual mortality of octogenarians averaged 13.7% vs. 5.2% for younger patients. At 2 years, octogenarian survival was at 94% of the expected 'normal' survival in the general population (vs. 96% for younger patients).
Conclusions: Surgical mortality of ruptured aneurysm repair was not independently related to advanced age but mainly driven by cardiac disease and manifest hypovolaemic shock. An almost normal long-term prognosis of aged patients after successful repair justifies even attempts of open repair, particularly in carefully selected patients.

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Rupture of abdominal aortic aneurysm is a catastrophic event that usually ends fatally if bleeding cannot be stopped in time. Emergency repair is the only potentially life-saving intervention. It is, however, associated with substantial mortality and morbidity even in relatively young and fit patients: the combination of profound haemorrhagic shock, lower body ischaemia and extensive reperfusion injury predisposes to systemic inflammatory response and multiple organ failure, particularly after open repair.[1] Therefore, many clinicians are reluctant to expose their patients to such an ordeal or to use associated resources unnecessarily if they consider the surgical risk prohibitive for the patient's physiologic reserves and, thus, the potential for successful recovery to be minimal. This is often assumed in elderly patients and may lead to unfair denial of potential rescue or to covert rationing if age thresholds were to be used uncritically.

Octogenarians are known to carry a higher perioperative risk of death than younger patients for elective aortic surgery,[2] and various surgical risks scores have suggested advanced age as an independent predictor of poor outcome also for ruptured aneurysm repair.[3] However, most of these scoring systems were derived on explorative analyses of historic data sets and none of them accounts for long-term recovery. A recent prospective evaluation of the most commonly used scores including Hardman index, Glasgow aneurysm score and Edinburgh ruptured aneurysm score yielded conflicting results and demonstrated their limited validity.[4] Of note, the score with the best predictive fit did not feature patients' age.

Interestingly, a recent report from the Swedish national registry suggested that octogenarians might even carry a relative survival benefit during long-term follow-up, at least after elective aortic repair.[2] By contrast, and although needed for informed decision making, evidence regarding impact of advanced age on ruptured aneurysm repair is scarce.[5] The largest available meta-analysis even excluded reports dealing with octogenarians explicitly.[6] Therefore, the aim of this study was to evaluate whether advanced age as such had an independent effect on perioperative mortality and carried prohibitive surgical risks for ruptured aneurysm repair. Secondary aim was to relate long-term prognosis of survivors to the life expectancy of a matched normal population.

Materials and Methods

A consecutive series of patients presenting with ruptured abdominal aortic aneurysm at a single centre in central Europe was analysed. The Swiss cardiovascular centre is a tertiary referral centre and attends a catchment area of roughly 1.5 million inhabitants. All patients were assessed between January 2001 and December 2010 and were offered open or endovascular repair at the discretion of the attending surgeon. Outcome was analysed between two age cohorts: one cohort included all patients at the age of or above 80 and the other consisted of younger patients. Cohorts were compared in terms of surgical mortality and long-term survival, and a predefined set of risk factors for early death was explored among octogenarians. In addition, survival estimates of both cohorts were related to expected 'normal' survival rates.

Patient identification

All patients admitted for abdominal aorto-iliac aneurysm repair during the predefined study period were potentially eligible and identified through interrogation of an in-house vascular registry that continually records all vascular surgery patients. All types of aneurysm were accepted including true, false and mycotic aneurysm at aortic and/or iliac level. Ruptured aneurysm was defined as presence of blood (or contrast medium) outside the aneurysm wall in an emergently presenting patient (Fig. 1). Clinically or radiologically suspected ruptures were to be reconfirmed during surgery. To avoid selection bias, completeness was cross-checked against the emergency department database and the hospital administration system, respectively (Fig. 1). In addition, all surgical records and discharge documents of the study period were cross-referenced by hand by one investigator (PO) and validated independently by a second (RvA). Patients who were not offered repair were considered for in-hospital mortality but excluded from surgical mortality. Patients with two ruptured aneurysms during the study period were included only at first rupture and follow-up was censored at second presentation. All patients or their relatives provided written informed consent for registration as well as for anonymous analyses, and ethical approval for the present investigation was granted by the local ethics' committee.

Exposure and outcome variables

Primary outcome measure was surgical mortality, which was defined as death from any cause within 30 days from ruptured aneurysm repair. Secondary outcome measures were (1) independent predictive value of patient-related risk factors for perioperative death among octogenarians and (2) relative long-term survival up to 3 years of follow-up. 'Normal' reference survival rates were calculated from national mortality statistics (Swiss federal agency of Statistics[7] and Human Mortality Database®[8]) using age, sex and calendar year-matched national population samples as described.[2] Baseline characteristics included age, sex, body mass index, cardiovascular co-morbidities and risk factors, renal function (i.e., glomerular filtration rate according to Cockcroft[9]), haemoglobin level, type and configuration of aneurysm, extent of rupture (contained vs. free), type of attempted repair (open vs. endovascular), preoperative arterial pressure and shock index[10] as well as intravenous volume used during resuscitation. Shock index was defined as ratio between heart rate and systolic blood pressure as measured at admission and before complete anaesthetic installation. Follow-up information included survival status at the end of 2010 including dates and causes of death, which were inquired from the Swiss federal agency of statistics. If information was not available, patients or relatives were contacted directly or, if unsuccessful, general practitioners, last treating doctors, healthcare insurances or municipal administrations. Long-term survival rates were estimated using Kaplan–Meier survival function to account for different lengths of follow-up. Patients were uncensored in the event of death (any cause) and censored when last known alive, in case of a second rupture or at the end of follow-up, which was truncated in January 2011.

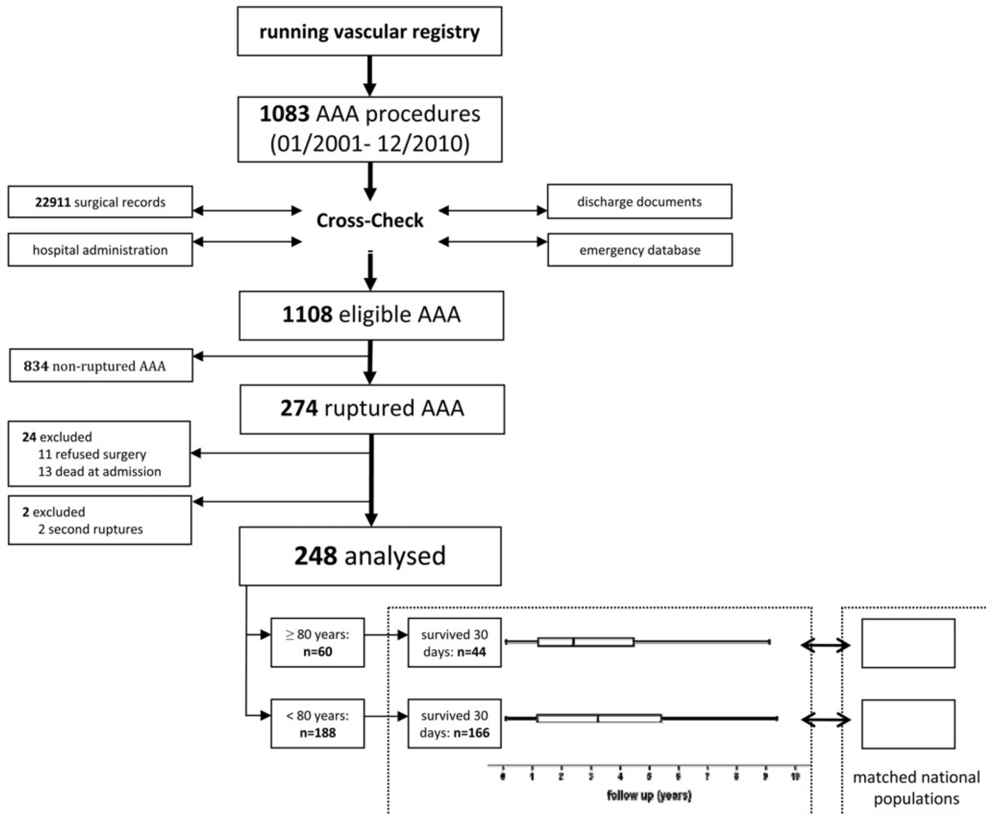

Figure 1 Study design including patient identification, selection and analysis. Abdominal aortic aneurysm (AAA) included all abdominal aneurysms at aortic and/or iliac level. Horizontal box-plots display median and inter-quartile range of available follow-up. Long-term survival was stratified for study cohorts and compared to expected 'normal' survival of a matched national population.

Data sources and missing values

Most data were available from the in-house registry, which continually collects a conventional range of patient- and procedure-related characteristics. All preoperative computed tomography (CT) scans and surgical records were reviewed to reconfirm diagnosis of rupture and to size the aneurysm, respectively, and haemodynamic condition was extracted from anaesthesia protocols in a structured process. Data were checked for plausibility and aberrant outliers. In case of missing values, alternative data sources such as hospital records were explored before imputation was considered.

Statistical methods

The statistical analysis plan was agreed before data were inspected, and analyses were performed in February 2011 using Statistical Package for the Social Sciences (SPSS) Statistics 17.0 for Windows. Characteristics are described using conventional summary statistics, that is, median with inter-quartile range (IQR), mean with standard deviation or absolute numbers (percentages) as appropriate. To minimise bias, continuous variables were generally assumed non-parametric and compared using Mann–Whitney *U* test. Proportions were compared using Fisher's exact test, and cumulative survival estimates using log-rank statistics. Surgical mortality was excluded for calculations of relative long-term survival. All tests used were two-sided, and differences were considered statistically significant for *P*-values of less than 0.05.

For comparisons of surgical mortality, logistic regression modelling was used to adjust for suspected confounding factors. Results are reported as odds ratios (OR) with 95% confidence intervals (CIs). Suspicion of confounding was based on established correlations with predictor and outcome variables, biological plausibility or inhomogeneous distributions at *P*-values <0.1. In cases of missing data, values were replaced by subgroup medians (e.g., weight or aneurysm size per gender) as long as patients with and without missing values were similar regarding other potential confounders, and only if $<10\%$ were missing. Categories were not imputed, but missing values were combined (category 'unknown'). Since in emergencies information is unlikely to be missing randomly, a conservative imputation strategy was considered to introduce less bias than simple exclusion of cases with missing data. Proportions of missing values are declared in Tables 1 and 2. The same model was used to explore the following risk factors among octogenarians regarding independent association with perioperative death: age and renal function (both as continuous variables), gender, presence of coronary artery disease or atrial fibrillation (both 'yes' vs. 'no' vs. 'unknown') and hypovolaemic shock at presentation

Table 1 Demographic and perioperative information.

Characteristic	Octogenarians	Non-Octogenarians	*P*-value
	n = 60	*n* = 188	
Male gender, *n* (%)	50 (83.3)	171 (91)	0.15[b]
Age in years	83 (81–85)	71 (65–75)	<0.001[a]
Shock index[d] in (beats/min)/mmHg	0.73 (0.57–1.02)	0.72 (0.56–0.97)	0.52[a]
Preoperative volume[e] in L/h	0.82 (0.58–1.05)	0.95(0.54–1.5)	0.82[a]
Haemoglobin level[f] in g/L	87 (72.2–102.7)	94.5 (78.6–112.1)	0.036[a]
Maximum aneurysm diameter in mm	80 (63–87)	80 (70–92)	0.41[a]
Location of ruptured aneurysm, *n* (%)			0.99[b]
Infrarenal	40 (67)	122 (65)	
Juxta-/pararenal	14 (23)	40 (21)	
Others[c]	6 (10)	22 (12)	
Missing information	0	4 (2)	
Iliac arteries involved, *n* (%)	19 (32)	77 (41)	0.43[b]
No iliac arteries involved	39 (65)	106 (56)	
Missing information	2 (3)	5 (3)	
Extent of rupture, *n* (%)			1.0[b]
Free	13 (22)	40 (21)	
Contained	47 (78)	148 (79)	
Ruptured aneurysm repair, *n* (%)			0.026[b]
Open	54 (90)	183 (97)	
EVAR	6 (10)	5 (3)	
Duration of repair in min	225 (170-268)	210 (170-289)	0.83[a]
Stay on ICU in d	4.0 (1.7–6.8)	3.1 (1.5–5.6)	0.37[a]
Hospital stay in d	13 (6-17)	12 (9-17)	0.52[a]

Summary statistics are given as median (inter-quartile range), if not specified otherwise.
EVAR, endovascular aneurysm repair; ICU, intermediate care or intensive care unit.
[a] Mann–Whitney *U* test.
[b] Fisher's exact test.
[c] Other locations include supra-renal as well as isolated common iliac and internal iliac aneurysm.
[d] At admission.
[e] Intravenous volume administered for resuscitation before surgical control of rupture, including crystalloid and colloid fluids as well as packed red cells.
[f] Lowermost preoperative haemoglobin level.

(shock index ≥1 vs. <1).[10] Long-term survival estimates were compared using Cox regression modelling and hazard ratios (HRs), and were additionally calculated as proportions of 'normal' survival as described.[2]

Results

Fig. 1 describes patient flow through identification and selection process. A total of 274 ruptured aortic aneurysms was identified. Twenty-four patients including 14 octogenarians (58%) were not offered repair for various reasons: 13 (six octogenarians) presented in critical condition after prolonged cardio-pulmonary resuscitation during transportation and were considered beyond remedy at arrival. Of the remaining 11 patients, seven (six octogenarians) refused surgery, and four (two octogenarians) were palliated because of known other end-stage disease. Two patients presented twice with a ruptured aneurysm and were censored at second presentation.

Therefore, a total of 248 operated patients was analysed per end point. Almost all were offered open repair (96%). Sixty were categorised octogenarian (24%) and had a median age of 83 years (IQR, 81; 85). Two-thirds of them (*n* = 41) had been admitted to another hospital first and were transferred subsequently. The corresponding proportion was similar in younger patients (*n* = 131, 70%). Aneurysm characteristics, shock index, haemoglobin level and volume needed for preoperative resuscitation were similar between age cohorts (Table 1). Use of resources (i.e., operating time, stay on intensive care unit and hospital stay) was also similar. Endovascular repair was used more often in octogenarians (Table 1).

Table 2 details cardiovascular co-morbidities and includes missing information. Octogenarians were more often affected by coronary artery disease, atrial fibrillation and impaired renal function. By contrast, body mass index and prevalence of diabetes and arterial hypertension were similar between cohorts.

Survival status at 30 days was known for all patients. Surgical mortality refers to 248 operated patients and was 15.3% at 30 days (*n* = 38 deaths). It was significantly higher in octogenarians (26.7% vs. 11.7%; *P* = 0.007). Half of these octogenarians died within the first 72 h (three during

Table 2 Co-morbidities and cardiovascular risk factors at time of repair.

Characteristic	Octogenarians	Non-Octogenarians	*P*-value
	$n = 60$	$n = 188$	
Glomerular filtration rate[c] in ml/min	48.3 (38.5–56.7)	59.6 (49.1–81.6)	<0.0001[a]
Diabetes mellitus, *n* (%)	8 (13)	24 (13)	0.11[b]
No diabetes	45 (75)	156 (83)	
Missing information	7 (12)	8 (4)	
Arterial hypertension, *n* (%)	51 (85)	151 (80)	0.82[b]
No arterial hypertension	7 (12)	30 (16)	
Missing information	2 (3)	7 (4)	
Coronary artery disease, *n* (%)	30 (50)	64 (34)	0.052[b]
No coronary artery disease	27 (45)	118 (63)	
Missing information	3 (5)	6 (3)	
Atrial fibrillation, *n* (%)	21 (35)	29 (15)	0.002[b]
No atrial fibrillation	35 (58)	151 (80)	
Missing information	4 (7)	8 (4)	
Chronic obstructive lung disease, *n* (%)	12 (20)	48 (26)	0.22[b]
No chronic obstructive lung disease	41 (68)	130 (69)	
Missing information	7 (12)	10 (5)	
Current smoker, *n*(%)	10 (17)	60 (32)	0.003[b]
Never smoked	32 (53)	56 (30)	
Ex smoker	11 (18)	57 (30)	
Missing information	7 (12)	15 (8)	

Summary statistics are given as median (inter-quartile range), if not specified otherwise.
[a] Mann–Whitney *U* test.
[b] Fisher's exact test.
[c] Calculated according to Cockcroft Gault formula.

surgery and five afterwards), the remaining eight died after 3 days. Of the 22 younger patients, 13 died within the first 72 h (six during surgery) and nine after 3 days.

In-hospital mortality refers to 272 admitted patients and was 20.5% ($n = 56$ deaths) corresponding to 36.5% in 74 admitted octogenarians ($n = 27$) and 14.6% in 198 younger patients ($n = 29$). The remainder ($n = 6$) died after hospital discharge but within 30 days of surgery.

Table 3 reports confounder-adjusted results of survival analyses. OR and HR indicate estimated changes of risk of death, and precision of estimates is indicated by 95% CI. Various levels of adjustment were calculated. Crude results were only adjusted for type of repair. Primary adjusted results compensated additionally for gender, renal function, preoperative shock index, haemoglobin level, extent of rupture and volume administered during resuscitation. Secondary adjusted results were calculated as primary, but compensated additionally for presence of coronary artery disease or atrial fibrillation. Of note, advanced age lost its independent association with increased risk of perioperative death when presence of coronary artery disease was considered. Free rupture was an important effect modifier (secondary adjusted OR 2.8; 95%CI, 1.1; 7.4; $P = 0.035$), whereas technique of attempted repair (i.e., open vs. endovascular) had no statistically significant effect (secondary adjusted OR 0.81; 95%CI, 0.09; 7.2; $P = 0.85$).

Table 4 details the risk factor analysis for octogenarians. Manifest hypovolaemic shock at presentation was the most important independent predictor of poor outcome in this age group.

Follow-up was available for a median of 2.4 years (IQR, 1.2; 4.5; max 9.1) in octogenarians vs. 3.2 years (IQR, 1.2; 5.4; max 9.4) in younger patients ($P = 0.41$, Fig. 1). Annual mortality of octogenarians averaged 13.7% ($n = 18/132$ person-years) as compared to 5.2% in younger patients ($n = 30/579$ person-years, $P < 0.001$). Causes of death are given in Table 5 and survival estimates are displayed in Fig. 2. Excluding surgical mortality, cumulative survival of octogenarians was 88%, 77% and 63% at 1, 2 and 3 years of follow-up, respectively. This corresponds to 97%, 94% and 84% of the expected 'normal' survival in a matched national population (Fig. 3). Corresponding figures for younger patients were 97% at 1 year (100% of expected normal survival), and 92% (96%) and 90% (96%) at 2 and 3 years, respectively.

Discussion

Every clinician who deals with vascular emergencies has come across the ethical dilemma of whether to offer or deny a probably hopeless but potentially life-saving intervention when an aged patient presents with ruptured aneurysm. Such decisions are typically based on emotional grounds as evidence is scarce to guide clinical decision making.[5] However, the challenge occurs not as rarely; in

Table 3 Association between age cohort and increased risk of death of any cause.

		Perioperative death		Death up to 1 year		Death up to 3 years	
		OR (95%CI)	*P*-value	HR (95%CI)	*P*-value	HR (95%CI)	*P*-value
Crude associations[a]	<80 years	1.0 (*ref.*)		1.0 (*ref.*)		1.0 (*ref.*)	
	≥80 years	2.9 (1.4–6.1)	0.004	2.7 (1.5–4.8)	0.001	2.9 (1.8–4.8)	<0.0001
Primary confounder-adjusted model[b]	<80 years	1.0 (*ref.*)		1.0 (*ref.*)		1.0 (*ref.*)	
	≥80 years	2.6 (1.1–5.9)	0.023	2.2 (1.2–4.2)	0.011	2.7 (1.6–4.5)	<0.0001
Secondary confounder-adjusted model[c]	<80 years	1.0 (*ref.*)		1.0 (*ref.*)		1.0 (*ref.*)	
	≥80 years	2.1 (0.9–5.2)	0.099	1.6 (0.8–3.1)	0.155	2.0 (1.2–3.5)	0.011

OR, odds ratio (using logistic regression modelling); HR, hazard ratio (using proportional hazards modelling).
[a] Adjusted for type of aneurysm repair (open vs. endovascular).
[b] Additionally adjusted for gender, renal function (according to Cockcroft), shock index, lowermost haemoglobin level before surgical control of bleeding, open vs. contained rupture, intravenous volume during preoperative resuscitation.
[c] Additionally adjusted for presence of coronary artery disease and atrial fibrillation (both as 'yes' vs. 'no' vs. 'unknown').

the current series, every fourth patient with a ruptured aneurysm was an octogenarian, and this was very similar in a recent National survey in Sweden.[2] Key finding of the present study was that even for open repair, octogenarians carried an acceptable surgical risk, which was mainly driven by a higher prevalence of coronary artery disease and was predicted by hypovolaemic shock. Given an almost normal life expectancy after successful repair, salvage attempts, therefore, seemed justified independently of age but under reserve of a responsible patient selection.

A perioperative mortality of almost 27% for octogenarians is considerable and reflects the severity of ruptured aneurysms. However, it still compares favourably to a pooled overall surgical mortality estimate of 41% for open repair,[6] particularly when it is considered that in this meta-analysis studies dealing specifically with octogenarians were excluded. There are a number of reasons why results of single specialist units tend to excel averaged outcomes many of which may impair generalisability. Nonetheless, such differences provide an important benchmark and may be taken as what centralised care can potentially achieve.[11]

Mortality differences between age groups are less systematic in aggregate observations than one would intuitively expect. For instance, a recent subgroup analysis of the Swedish Vascular registry reported a similar perioperative mortality for octogenarians (51%)[2] as above meta-analysis which had excluded them. In the present study,

Table 4 Risk factor analysis for perioperative death among octogenarians ($n = 60$).

Characteristic	OR (95%CI)	*P*-value
Age, per year increment	1.1 (0.9–1.3)	0.58
Male gender	0.5 (0.7–3.0)	0.41
Glomerular filtration rate[a], per ml/min increment	1.0 (0.9–1.0)	0.32
Haemoglobin level[b] per g/L increment	1.0 (1.0–1.0)	0.40
Shock index[c]		
<1.0	1.0 (*ref.*)	
≥1.0	5.1 (1.1–23.4)	0.037
Coronary artery disease		
No	1.0 (*ref.*)	
Yes	2.2 (0.5–10.0)	0.31
Unknown	4.9 (0.2–100.0)	0.30
Atrial fibrillation		
No	1.0 (*ref.*)	
Yes	1.1 (0.2–5.0)	0.92
Unknown	8.8 (0.5–156.0)	0.14

Analysis was adjusted additionally for extent of rupture and type of repair. OR, odds ratio (using logistic regression modelling); CI, confidence interval.
[a] According to Cockcroft Gault.
[b] Lowermost level before surgical control of bleeding.
[c] In (beats/min)/mmHg.

Table 5 Causes of death during follow-up (>30d, $n = 210$).

	$n = 48$
Related to aneurysm repair[a]	1
Cardiac	16
Cerebral	3
Cancer	7
Gastrointestinal	3
Pulmonary	5
Renal failure	1
Not known	12

[a] Ruptured false aneurysm at anastomotic site.

the survival benefit of younger patients was sustained only as long as results were not adjusted for presence of coronary artery disease (Table 3). The suggested confounding is biologically plausible as the fatal sequence of sudden hypovolaemic shock and lower body ischaemia followed by extensive reperfusion injury impacts primarily on cardiac reserves.[1] Accordingly, cardiac disease predicted not only perioperative death but was also the reason for most deaths during follow-up (Table 5).

Hypovolaemic shock was an independent predictor of perioperative death in octogenarians. This is consistent with the Edinburgh ruptured aneurysm score which features absolute systolic blood pressures below 90 mmHg as one of its key parameters. However, increased heart rate is the body's first reaction to haemorrhagic shock.[12] The shock index relates the heart rate to the perfusion pressure at organ level and could be more sensitive than absolute pressures. Indeed, there is convincing evidence from trauma series that shock index correlates directly with the need for massive transfusion in relatively normotensive patients,[13] with important indices of impaired organ

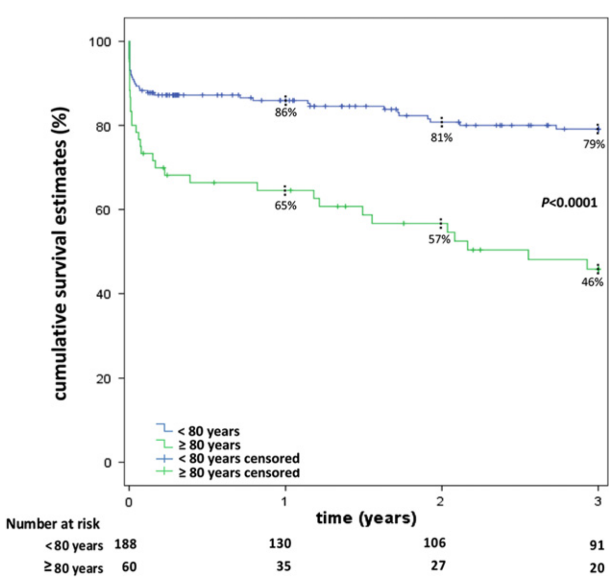

Figure 2 Cumulative survival estimates after attempted repair of ruptured aneurysm. Kaplan–Meier survival curves for study cohorts up to three years after attempted aortic repair. All causes of death were included and are detailed in Table 5. Comparison of survival functions by Log-rank test.

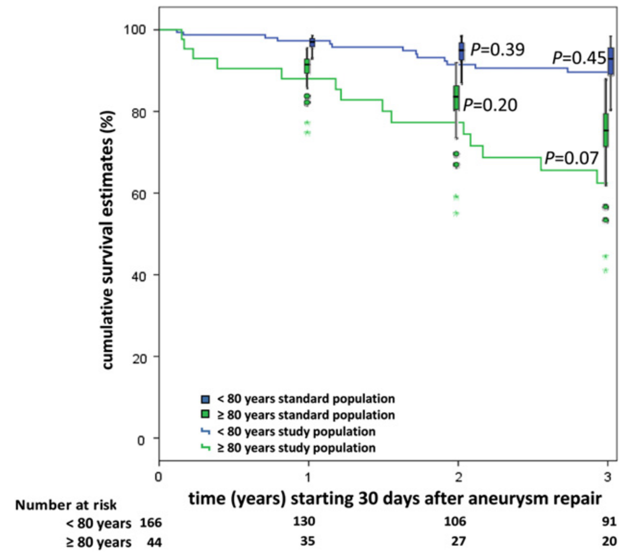

Figure 3 Comparison of postoperative survival with expected 'normal' survival. 30-day mortality was excluded from this analysis. Cumulative survival estimates of study cohorts are compared to the expected 'normal' survival of matched national population (in terms of age, gender and calendar year). Expected 'normal' survival is displayed using box-plots indicating medians and inter-quartile ranges. Comparisons by Fisher's exact.

perfusion such as central venous oxygen saturation,[14] and with mortality.[15] Hence, shock index had been predefined as a potential risk factor in the current analysis.

The concept of 'prohibitive surgical risk' clearly depends on the natural history of the condition. For ruptured abdominal aneurysm, the natural history is deleterious.[5] For similar emergencies such as aortic type A dissection or cardiogenic shock in the context of severe aortic valve stenosis, surgical mortality rates between 30% and 38% have been perfectly acceptable for octogenarians.[16,17] Therefore, a 27% mortality should not discourage attempts of emergency repair — particularly as age as such was a poor predictor of outcome. Thus, critical evaluation of aged patients presenting with severe coronary artery disease or haemorrhagic shock seems much more promising to improve overall survival than to refuse patients solely based on their age.

Potential for recovery is another important determinant for surgical decision making. Not surprisingly, absolute prognosis after successful repair was better for younger patients. However, survival prognosis was in the normal range for both cohorts if compared to matched national population samples (Fig. 3). Others have reported similar findings.[18] For instance, a recent population-based Swedish survey reported a relative survival of 94% of the adjusted national life expectancy up to 5 years after repair.[2] In the current series, such excellent outcome was found only during the first 2 years for octogenarians; after that relative survival declined to 84% at 3 years (Fig. 3). Part of this difference may be explained by the fact that 90-day mortality was excluded in the Swedish survey whereas only 30-day mortality was excluded in the present series. Absolute survival rates after emergency repair ranged from

48 to 68% at 5 years in a systematic review, but they were not stratified for age.[19] For comparison, pooled 5-year survival estimates after elective aneurysm repair were at 60% for octogenarians.[20] This suggests that long-term outlook after ruptured aneurysm repair is mainly determined by the perioperative rather than the postoperative course, which followed the normal pattern of a matched reference population independently of age in a number of studies.

The study has potential limitations that may affect the validity of the findings. First, the dataset is not randomised and, thus, susceptible to confounding. However, as the effect of an epidemiological factor (age) was investigated, randomisation is obviously impossible and comparison of prospective cohorts represents the next best alternative. To limit confounding, multivariable statistics were used to account for known or suspected undue influences. Second, identification and selection of patients is particularly challenging when emergency interventions are investigated, as patient paths tend to vary unpredictably. Although selection was based on a prospectively maintained computer database, every effort was given to guarantee consecutivity by additional predefined cross-referencing. By contrast, selection bias by incomplete referral cannot be excluded. In the absence of systematic autopsy surveys, the estimated number of unreported cases of missed or not referred ruptured aneurysms is essentially unknown. However, for those patients who entered a hospital within the catchment area, referral paths are firmly established and maintained by close collaboration, hence were close to 70% of patients were secondary referrals and, as distances are relatively short, some patients were even sent under ongoing resuscitation. Therefore, it is unlikely that many patients were palliated outside without consultation. Third, emergency series are prone to missing data, as priority is always given to patient care and not to data sampling. Hence, a number of alternative data sources were searched in addition to the computer database, which improved overall data completeness to 94%. For effectively missing data, a conservative imputation approach was chosen to prevent selection bias by excluding patients with missing data from analysis. Fourth, the series involved almost exclusively open repair. Although type of repair was accounted for within multivariate adjustment and did not influence results, generalisability may be limited. Endovascular repair has been reckoned to improve outcome of ruptured aneurysm, particularly in elderly and frail patients[1,5]; however, its use is still quite limited in current practice.[2,5] Therefore, the present findings can still be considered representative and, if anything, would probably underestimate the outcome of octogenarians.

To summarise, 'prohibitive' surgical risks are not absolute but need to be balanced against expected natural course and available socio-economic resources. The desperate prognosis of untreated ruptured aneurysm justifies liberal use of rescue interventions. Even in this predominantly open repair series, advanced age as such did not predict failure but was confounded by important risk factors such as coronary artery disease and limited reserves to cope with haemorrhagic shock. Endovascular repair might be particularly appropriate in this frail subset of patients and has the potential to improve their prognosis further. As life expectancy after successful emergency repair was almost normal across age cohorts, denial of a life-saving operation solely based on age does not seem warranted.

Conflict of Interest/Funding

None declared.

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