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Considerations with Respect to Elective Abdominal Aortic Aneurysm Repair in Older People

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Background: The epidemiology of abdominal aortic aneurysm (AAA) is changing, with progressively more older patients receiving repair. Advancing age associates with an increased procedural risk but also with a decreasing lifetime rupture risk. This national study aims to provide background information for decision-making in older people.

Methods: National administrative data (Statistics Netherlands) were used to estimate time-varying trends in the age and sex distribution of patients who underwent AAA repair, the age-procedural-risk relationships, and survival-time following successful AAA repair.

Results: Between 1995 and 2023, 48,557 patients underwent elective AAA repair. The mean age at repair increased from 69.9 to 73.9 years ($P < 0.001$). The proportion octogenarians almost tripled from 7.3% to 21.4%, and the proportion of women increased from 11.1% to 15.3% (both $P < 0.001$).

Age-at-repair strongly influenced median survival following elective repair; mean survival following repair for 70-year-old patients equaled 10.1 years for men and 8.7 years for women but decreased to 6.2 and 6.1 years for men and women at 80 years. A progressive age-at-repair- 90-day mortality risk relationship was observed for open repair, with the risk exceeding 5% in patients over 75 years. Risk was more pronounced in women. Procedural risk for endovascular repair (90-day mortality) was less than 2% and 3%, respectively, for men and women under 80 years, but risk increased for those over 80 years.

Conclusion: Implementation of age-specific intervention thresholds appears justified. Considering their high procedural risk for open repair, conservative or deferred management should be considered in women over 77 years who are not eligible for endovascular repair.

INTRODUCTION

Although abdominal aortic aneurysms (AAAs) are generally clinically silent, they can rupture, often resulting in a catastrophic hemorrhage and death.[1,2] Risk of rupture is minimal for small AAAs but progressively increases for 'larger' AAA (commonly defined as 55 mm and over). Consequently,

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prevailing guidelines universally advise watchful waiting for small AAA and elective repair once the aneurysms reaches 55 mm (possibly slightly earlier in women).[1,2] This 55-mm intervention threshold reflects the conservative balance between the lifetime rupture risk and surgical risk, since multiple trials showed no benefit from earlier repair.[3,4,5,6]

Remarkably, while most guidelines now address sex-associated differences in rupture risk and recommend earlier repair in women, the potential impact of age on the risk-benefit balance in an aging patient population is not specifically addressed. While older age comes with a higher risk for surgical complications, the shorter life expectancy of older individuals results in a reduced lifetime benefit of a repair (because of the lower number of years at-risk for rupture).[7,8,9] On these grounds, it was reasoned that the ''one size fits all'' 55-mm decision-making threshold for elective AAA repair may insufficiently incorporate the shift in risk-benefit balance that occurs during aging.

In order to inform the field and policy-makers, we here describe the influence of age on the risk-benefit balance for elective AAA repair in male and female Dutch AAA patients.

METHODS

The study is approved by the governing body of the Statistics Netherlands and is performed in accordance with the Dutch legislation with respect to the secondary use of data.[10]

Study Population

This study relies on linkable national data that are accessible through Data Statistics Netherlands.[11] Registries used in these studies were the Hospital Discharge Registry (Landelijke Medische Registratie up to 2011 and Landelijke Basisregistratie Ziekenhuizen for the years 2013−2023), Population Registry, and National Cause of Death Registry (accessed until December 31, 2024).

This study includes all patients who underwent elective AAA repair between 1995 and 2023 in the Netherlands. Identification was performed in a two-step approach. First, all individuals with a hospitalization code for ''intact AAA'' (International Classification of Diseases [ICD]-9: 441.4 or ICD10: I171.4) were selected from the Hospital Discharge Registry. Subsequently, those receiving AAA repair on the basis of the intervention code were selected (see Table I for the codes applied). Patients with a diagnosis of ruptured AAA (ICD-9: 441.3 or ICD10: I171.3) or without a procedural code were excluded. Adequacy of the case identification strategy in the Statistics Netherlands data was validated through cross-referencing with the annual number of elective procedures registered in the mandatory Dutch Surgical Aneurysm Audit (DSAA).[12]

For each identified patient, we extracted sex, date of birth, and date of admission, and for deceased patients, the registered date of death recorded in the Dutch Population Registry. Note that information on the type of repair (open surgical repair or endovascular aneurysm repair [EVAR]) is only registered for procedures performed in 2013 and onwards.

Due to transient postponement of mandatory hospital registration, the proportion of missing cases in the Statistics Netherlands data increased from 5% to 25% for the years 2005−2013. Due to technical issues, no hospital registration data are available for the year 2012.

Outcome Measures

Annual mean age-at-repair and the proportions of female patients and octogenarians were calculated for the period 1995−2023 to estimate the temporal trends for the AAA population.

Ninety-day mortality risk was estimated for 2013−2023 time interval because Statistics Netherlands did not register the data on the type of AAA repair for the earlier years. Moreover, this period represents the contemporary ''EVAR-first'' period, in which EVAR was prioritized when feasible.

Estimation of age-specific life expectancy following successful repair (i.e., survival time conditional on 90-day survival, thus excluding procedural mortality) requires longer follow-up times to fully capture all survival quartiles and therefore included earlier years. Estimates were based on the most recent time intervals possible to provide contemporary survival information. This approach is justified by previous reports showing that long-term survival after successful elective AAA repair remained stable over time[9] and is similar for EVAR and open repair.[13]

Statistics

Statistical analyses were performed using R Statistical Software (V4.3.1; R Core Team 2024) and the survival package. For descriptive analysis, the mean age at repair and the proportion of women and octogenarians were calculated for each year from 1995 to 2023. Age group−specific long-term survival times (25th, 50th, and 75th percentiles, conditional on 90 days of survival) were estimated using Kaplan-Meier methods, with dynamic period

Table I. Diagnostic (ICD-9 and ICD-10) and procedural (CW, CBV, and ZA) codes used for patient inclusion

Diagnosis	Intact AAA
ICD-9 code	441.4
ICD-10 code	I174.4

Procedure	Codes
CW codes	3313, 31310, 31311, 31313, 31318, 31319, 31380, 31390, 88368, 538040, 538090, 538090, 538241, 538242, 538244, 538330, 538331, 538332, 538333, 538334, 538335, 538336, 538337, 538338, 538540, 538541, 539525, 539570, 539575, 539590, 539595, 539980, 539985, 539990, 539995, 883603, 883606, 883653, 883656
CBV codes	33520, 33521, 33554, 33555, 33559, 33560, 33561, 33562, 33699, 80930, 190302, 333532, 333533, 333534, 333535, 333536, 333537, 333538, 333539, 333553, 333555, 333556, 333558, 380020, 385332, 388922, 3,331530, 333153L, 333153M, 333153R, 333153X, 333153Y, 333154A, 333154B, 3335300, 333530A, 333530C, 333530G, 333530H, 333530J, 333530K, 333530M, 333530*N*, 333530P, 333530R, 333532A, 333532B, 333532C, 333532D, 333532E, 333532F, 333533A, 333533B, 333539B, 333539BA, 333555A, 333555B, 333556C, 333556D, 333556E, 388932A
ZA codes	33520, 33521, 33554, 33555, 33556, 33557, 33558, 33559, 33560, 33561, 33562, 80821, 80822, 80823, 80930, 190302

selection. To be more specific, estimates prioritizing the most up-to-date interval were prioritized in order to optimally reflect current outcomes but were extended to earlier periods if the mortality did not allow for full estimation of the reported quartiles (time intervals applied are provided in Supplemental Table 2). The results were stratified by age, with survival curves plotted for both sexes.

RESULTS

Patient Age and Life Expectancy Following Elective Repair

Statistics Netherlands data from January 1995 to December 2023 register 48,557 patients who underwent elective AAA repair. The mean age at repair was 72.2 years, with 15.6% being octogenarians, and 86.4% of the patients were male. The data indicate clear shifts in patient demographics over the 2 decades. From 1995 to 2017, the mean age-at-repair increased from 69.9 to 73.9 years (p for trend <0.001, Fig. 1A), the percentage of women increased from 11.1% to 15.3% (Fig. 1B), and the proportion of octogenarians receiving repair rose from 7.3% to 21.4%, (P for trend <0.001, Fig. 1C).

Life Expectancy Following Elective AAA Repair

The observed age-at-repair life expectancy (median and interquartile ranges) relationship following successful elective AAA repair (i.e., conditional on 90-day mortality) for each sex is summarized in Figure 2A (males) and 2B (females). For 70- and 80-year-old male patients, the median survival times following elective repair were 10.1 years and 6.2 years, and for female patients, the median survival times were 8.7 and 6.1 years, respectively.

Mortality Risk Following Elective AAA Repair

Figure 3A(men) and 3B (women) show the age-procedural risk (defined as 90-day mortality) for elective open and endovascular procedures

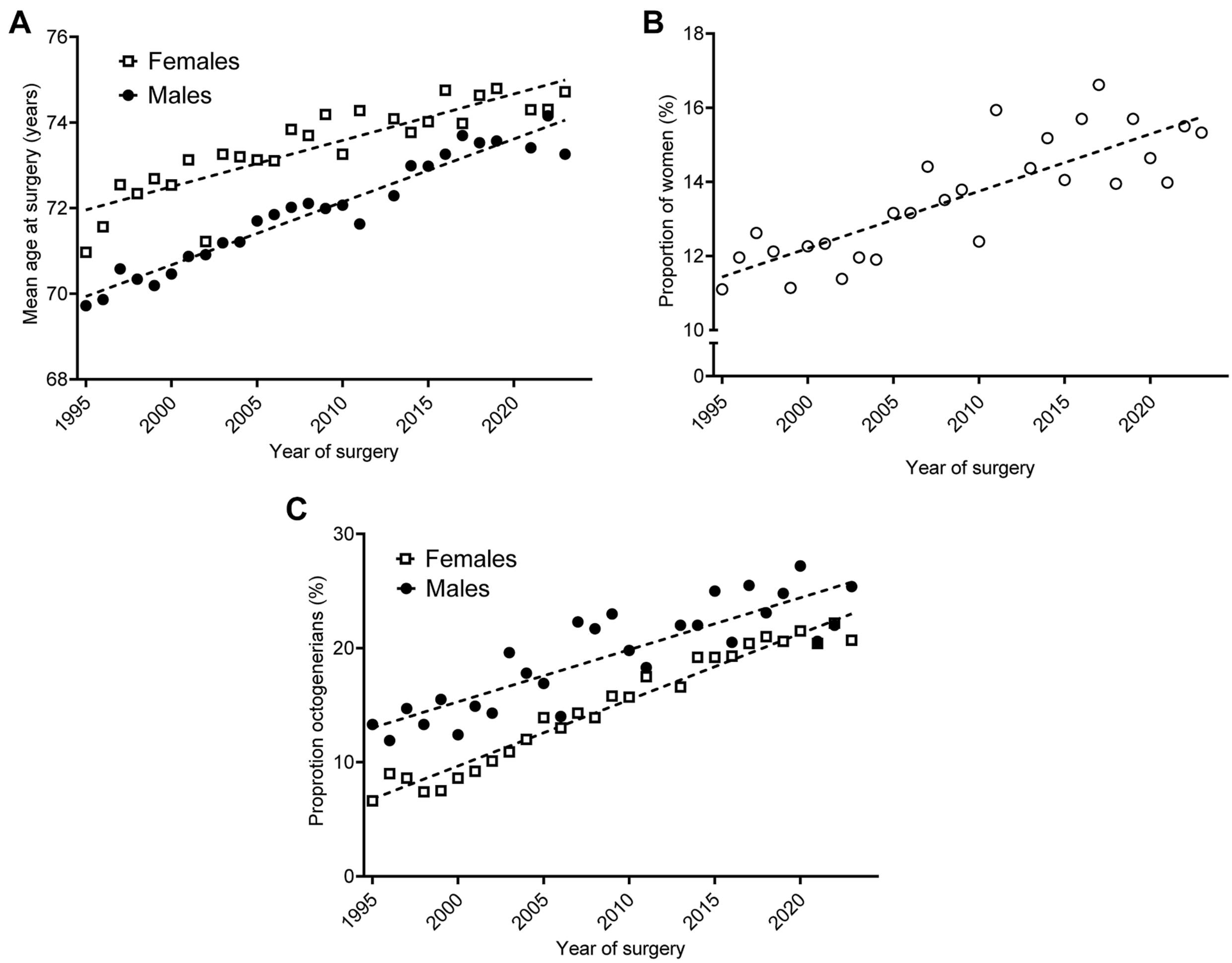

Fig. 1. A-C. Changes in the demographics of patients receiving AAA repair over the 1995–2023 interval. From 1995 to 2023, the mean age at repair **(A)**, the proportion of female patients **(B)**, and the proportion of octogenarians **(C)** receiving elective AAA repair rose significantly.

performed between 2013 and 2023. For open repair, 90-day mortality increased progressively with age, from <4% for men below 70 years up to 8% in octogenarians, for women progressively worse outcomes with increasing age. For EVAR, 90-day mortality risk was less influenced by the age at repair, remaining below 2% in men. A consistently higher 90-day mortality ($OR_{\text{corrected for age}}$ for death: 1.52 [1.08–2.11] (men is reference)) was observed for women over 70 years of age (Fig. 3B). Thirty-day mortality is shown in Supplemental Figure 1

DISCUSSION

This analysis, based on national administrative data, provides relevant information with respect for discussions on the timing of elective repair in elderly patients. The data illustrate the significant demographic shifts in the patient population receiving elective AAA repair over the past 3 decades. Notably, the mean age-at-repair increased, with progressively more repairs being performed in octogenarians. A higher age-at-repair negatively impacts the risk-benefit balance of elective AAA repair because it positively associates with procedural risk but negatively with the lifetime-benefit of repair. It could be argued that this shift in risk-benefit balance potentially favors higher intervention thresholds for older patients.

Administrative data for the Netherlands, a country without AAA screening, illustrate how temporal shifts in the epidemiology of AAA[14] and the introduction of EVAR over the last decades have altered the characteristics of patients undergoing elective AAA repair.[15,16] The median age-at-elective-repair

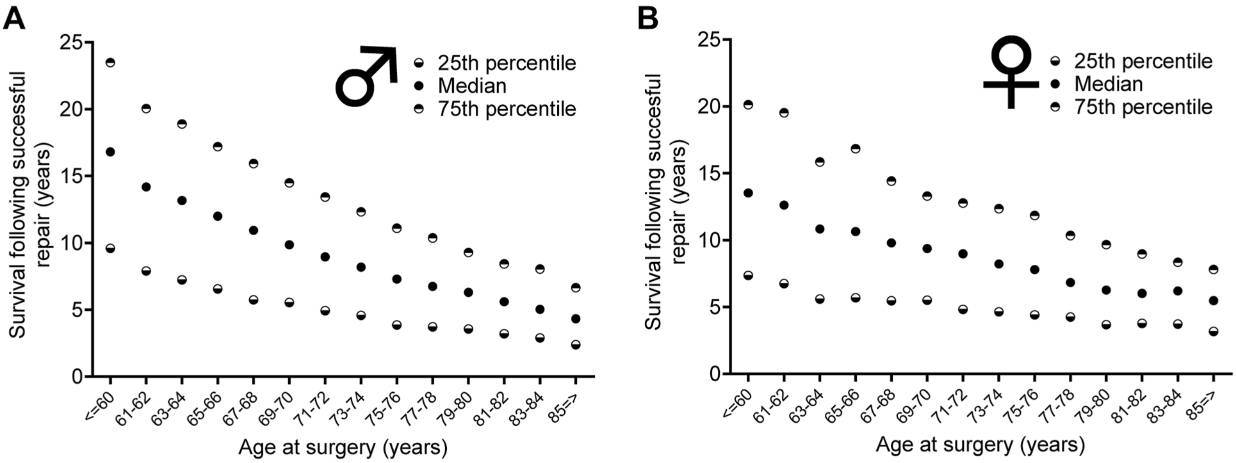

Fig. 2. **(A)** (males) and **(B)** (females). Age-specific survival following successful elective AAA repair (i.e., conditional on 90-day survival) for male and female Dutch patients (median and interquartile range).

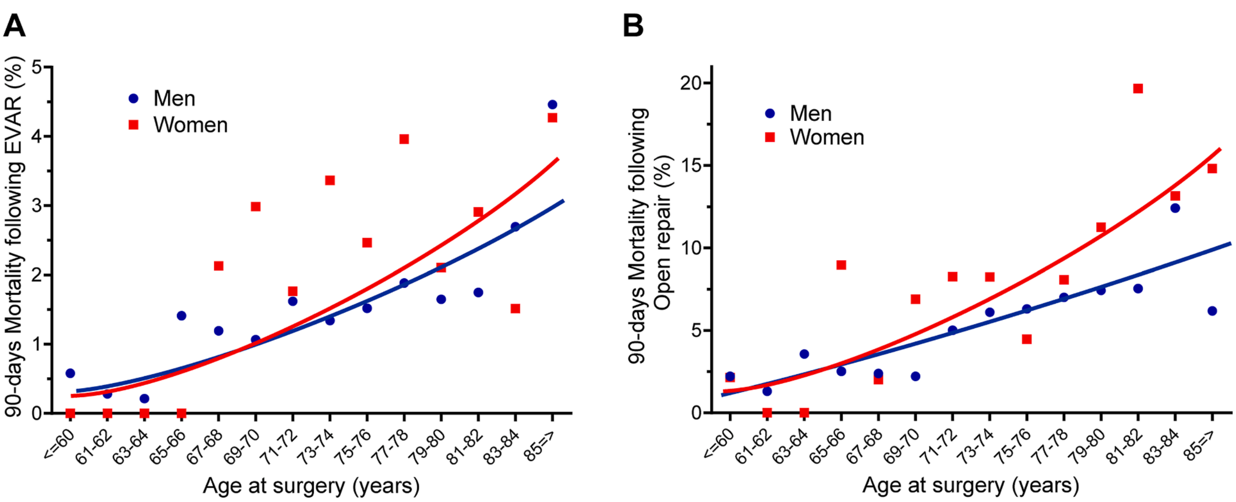

Fig. 3. **A** and **B** The age -90-day mortality risk relationships for elective EVAR (Fig. 3**A**) and open repair procedures (Fig. 3**B**) performed between 2013 and 2023 in the Netherlands. The blue curves represent men; the red curves represent women. Note that the small number of observations, particularly for women in the youngest and oldest age groups, may result in greater variability of estimates at these extremes and should be interpreted with caution.

for men rose from nearly 70 years in 1995 (an intervention age almost similar to that in the United Kingdom (UK) Small Aneurysm Trial[3] that included patients between 1991 and 1995) to 74 years for the current Dutch AAA population. The shift in age-at-elective repair translates into shorter time-to-live following repair and consequently a lower lifetime benefit of a repair. Conversely, the data show strong (open) and moderate (EVAR) progressive age-risk relationships for elective repair, illustrating the dichotomic impact of age on the risk-benefit balance of elective AAA repair. A critical question is whether this should translate into age-specific intervention thresholds. Because the UK small aneurysm trial,[3] later trials,[4–6] and observational data[17] have shown no benefit for repairs below the 55 mm threshold, the 55-mm intervention threshold (for men) now remains the basis for all societal guidelines.[1,2] However, it is important to point out that the evidence is derived from younger trial populations, and that, the safety and utility of larger intervention thresholds have not been evaluated. Consequently, the current 55-mm intervention diameter should be considered as a conservative estimate.[18]

While societal guidelines universally adhere to the 55-mm intervention threshold for men and now incorporate specific advice for women (earlier repair),[1,2] no specific recommendations are included for older patients. This is remarkable considering the changes in the epidemiology of AAA with a progressive shift toward older age and the positive association between procedural (repair) risk and age. In parallel, older age associates with a reduced lifetime rupture-risk as a direct consequence of the negative relationship between age and life expectancy. Consequently, even if the annual rupture risk increases as a result of the aneurysm growth, the overall probability of ever experiencing a rupture may actually decrease with rising age.[18] Collectively, these aspects will most likely influence the risk-benefit balance for elective repair in older individuals.[19] Still, further modeling studies and insight into the patients' attitudes toward postponed repair are required for possible implementation-studies can be initiated.

Life tables based on the national administrative data for the Netherlands illustrate the unequivocal inverse relationship between age-at-repair and life expectancy. Although AAA disease associates with a compromised life expectancy,[9] a degree of flattening of the survival following elective repair curves was observed with increasing age. This flattening may reflect a more healthy aging genotype/phenotype in these ''survivors'' but may also involve aspects of medical decision-making, with fitter older patients being more likely to be offered or request elective repair than more frail patients, thereby introducing a potential source of bias (i.e., confounding by indication[20]) when interpreting these data. The survival data further indicated a notable reversal of the survival benefit that is normally observed for women versus men. In fact, life expectancies for 'younger' women were profoundly worse than for men of the same age. An observation further illustrates the persistent poor long-term survival prognosis for women after successful AAA repair.[9,21] We relied on 90-day mortality as an estimate of procedural risk. It has been pointed out that 90-day mortality better captures procedure-related short-term mortality and is a better indicator of 1-year mortality than 30-day mortality.[22,23] Analyses were based on the most recent timeframe in order to reflect the current practice, and because data on the type of procedure in the Statistics Netherlands data are only available for repairs performed in 2013 and later.

The observed procedural risks may appear higher than those reported in the literature.[24] This obviously relates to the fact that this study relies on 90-day mortality rather than the more commonly reported 30-day mortality.[18,19] A second aspect to consider in the interpretation of the available data is the phenomenon of regression-to-the-mean, as most other studies report population-based rather than age-specific risk estimates. As a result, excess mortality in the generally smaller group of older patients is diluted by the lower incidence in younger patients. Procedural risk (defined by survival status at discharge or 30 days) for Dutch octogenarians has been previously reported in an earlier evaluation based on the Dutch Surgical Aneurysm Audit data.[15] Observed difference between the earlier report and the current report obviously reflect the different time horizons used but may also involve underreporting in the registry study as a result of the reliance on hospital data for the 30-day mortality data,[15] as opposed to national administrative data in the current study.

While the age of 80 years is often used to define the ''older old,'' our data indicate an age-risk inflection point for elective repair at a younger age, and the age of 75 years emerged as a transition point above which the procedural risk for open repair increases progressively.

While it cannot be excluded that the observed high procedural mortality for open elective repair in patients over 75 years of age relates to the repair of frail patients, it should be acknowledged that decisions for elective open repair are made after a process of deliberate medical decision-making. This aspect is reflected by the fact that only a small proportion of the patients receiving elective open repair classifies as frail (e.g., less than 3.5% in the vascular quality initiative (VQI)[25] and other cohorts[26,27]). Consequently, we consider that less likely procedures performed in frail individuals are a major determinant of the observed high procedural mortality rates for open repair in older patients. Instead, the data suggest that the current risk assessment strategies for older AAA patients might be suboptimal, and that, the field would benefit from improved risk assessment aids when considering open repair in older individuals. In this respect, the observed higher procedural risk and a particularly steep age-risk relationship for open repair in women merit special attention. These findings align with other reports such as that from the Society for Vascular Surgery Vascular Quality Initiative,[25] which also concluded that female sex is an independent risk factor for procedural mortality following open repair.

The observed impact of age on the procedural risk for EVAR contrasts with registry data[28] but aligns with the conclusions for a recent meta-analysis.[20]

Notwithstanding, the absolute impact of age is relatively modest given the low procedural risk associated with elective EVAR. Concerningly, this evaluation confirmed earlier signals of a relatively high procedural risk for EVAR in women, with higher observed mortality rates among women aged 80 years and older.[29,30]

The inverse association between age and lifetime rupture risk, along with the increasing procedural risk in older patients, result in a clear shift in the risk-benefit balance of open repair with advancing age. The question arises whether, and if so to what extent, this shift should translate into recommendations for a higher intervention threshold in older individuals. Available evidence with respect to the diameter-risk relationship for larger AAA has been integrated in a systematic review and meta-analysis by Parkinson et al. in 2014.[31] Conclusions of this review have been revised and updated in a scoping review that accompanies this report.[18] Conclusions from this reevaluation suggest that the overall rupture risks are even lower than the—already lower than generally assumed risk—[32,33] as predicted in the meta-analysis of Parkinson et al.[31]

The high 90-day mortality rates call for specific guideline recommendations regarding *open* elective repair in older patients, i.e., whether these procedures should be restricted to the healthiest elderly (if so based on which criteria?) and to the best teams and whether it should preferably be postponed to larger diameters. Although EVAR comes with a significantly lower procedural risk, this risk should still be balanced against a lower lifetime-rupture-risk in older patients. A more restricted policy with repair postponed to 60 mm or even higher warrants a prospective study. In this, a critical aspect will be patients' education because many patients perceive the 55-mm threshold as a critical tipping point above which the rupture risk increases dramatically.[34] In fact, it is reported that 50% of the interviewed patients thought that a threshold of AAA equates to certain death or rupture.[35]

The compromised outcomes in women call for special attention. While the current guidelines recommend earlier repair in women, this recommendation may need revision in light of the substantially higher procedural risk for EVAR in women,[36,37] despite only a slightly higher rupture risk.[27]

Limitations

This study has several limitations. It is based on administrative data, as such interpretation is interfered by aspects of confounding. Detailed patient information such as comorbidities and aneurysm characteristics were not available. Consequently, the impact of patient characteristics (frailty, comorbidity) or center effects on the mortality cannot be addressed. However, as also indicated by the flattening survival-after-elective-repair curves at advanced age, it is likely that all decisions with respect to elective repair were performed after a process of medical decision-making, balancing the risk-benefit for each individual patient. In this respect, it should be noticed that the performance of surgeon's judgment (eye-balling) with respect to mortality risk equals to that of a dedicated frailty index (VQI-derived Risk Analysis Index).[26] Because of their relative underrepresentation, conclusions with respect to women should be interpreted with caution. Given the low incidence of AAA in women and, as a consequence, the restricted power of these (and many other) studies, a multinational study is warranted to provide more reliable risk estimates for elective AAA repair in women.

CONCLUSIONS

Age-at-repair negatively impacts both the procedural risk and the time-of-benefit from elective AAA repair. For older patients, especially those undergoing open repair, the immediate risk of surgery may not outweigh the possible future benefits. The persistently high mortality among women for both open surgical repair and EVAR raises further concerns and calls for reevaluation of the current recommendation for earlier repair in women. Together, these findings suggest that the universal sex-specific thresholds should be reconsidered and complemented with age-specific considerations to optimize decision-making in elective AAA repair.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Mathijs J. Biemond: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Jitse H.M. Paping:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Ruth M.A. Bulder:** Writing – review & editing, Formal analysis, Data curation. **Rebecka Hultgren:** Writing – review & editing. **Simon P. Mooijaart:** Writing – review & editing. **Jaap F. Hamming:** Writing – review & editing. **Jan H. Lindeman:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.avsg.2025.11.125.

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