REVIEW

Rupture Rates of Small Abdominal Aortic Aneurysms: A Systematic Review of the Literature

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Abstract

\textbf{Background:} Small aneurysms of the abdominal aorta (3.0–5.5 cm in diameter) often are managed by regular surveillance, rather than surgery, because the risk of surgery is considered to outweigh the risk of aneurysm rupture. The risk of small aneurysm rupture is considered to be low. The purpose of this review is to summarise the reported estimates of small aneurysm rupture rates.

\textbf{Methods and findings:} We conducted a systematic review of the literature published before 2010 and identified 54 potentially eligible reports. Detailed review of these studies showed that both ascertainment of rupture, patient follow-up and causes of death were poorly reported: diagnostic criteria for rupture were never reported. There were only 14 studies from which rupture rates (as ruptures per 100 person-years) were available. These 14 published studies included 9779 patients (89% male) over the time period 1976–2006 but only 7 of these studies provided rupture rates specifically for the diameter range 3.0–5.5 cm, which ranged from 0 to 1.61 ruptures per 100 person-years.

\textbf{Conclusions:} Rupture rates of small abdominal aortic aneurysms would appear to be low, but most studies have been poorly reported and did not have clear ascertainment and diagnostic criteria for aneurysm rupture.

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Introduction

In the 1990s, two randomised trials were conducted which showed that early open surgical repair of small abdominal aortic aneurysms (versus surveillance) was not associated with a long-term survival benefit for these patients and was more costly.\textsuperscript{1-2} More recently, two randomised trials have shown that early endovascular repair of small abdominal aortic aneurysms (versus radiological surveillance) was not associated with a mid-term survival benefit.\textsuperscript{3,4} The main reason that none of these trials of intervention for small aneurysms has shown a survival benefit for patients is because the risk of aneurysm rupture is very low whilst the aneurysm is still small. This low risk of aneurysm rupture makes it difficult to obtain either reliable estimates of rupture rates or investigate how these rupture rates vary according to aneurysm size, gender and other patient characteristics. Reliable estimates of small aneurysm rupture rates would be informative for the management of small aneurysms, since today screening of populations for small aneurysms has become popular and the majority (80–90\%) of all patients with small screen-detected aneurysms are managed in surveillance programmes.\textsuperscript{5,6}

Although some synthesis of data for rupture in large aneurysms has been reported previously,\textsuperscript{7} systematic reviews and meta-analyses of studies focussed on the rupture rate of small aneurysms (<5.5 cm) have not been reported recently. The aim of this review is to summarise the currently published data from systematically identified studies on rupture rates for small aneurysms measuring between 3.0 and 5.5 cm.

Methods

Systematic review, protocol and registration

The systematic review followed quality reporting guidelines set by the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) group (http://www.prisma-statement.org/).\textsuperscript{8} Therefore a review protocol, that outlined every step of the systematic review including exclusion criteria, was developed before starting the literature search and subsequent data extraction. The protocol was reviewed and approved (author FGRF).

Search strategy

Medline, EMBASE on Ovid SP, CENTRAL Issue 3, 2009, ClinicalTrials.gov, and controlled-trials.com were searched up until the end of 2009 using search strategies shown in Web Appendix I. Initially, there were no filters used to restrict study designs, nor were there any language restrictions. In addition, reference lists were also searched for further studies to be included.

Eligibility criteria, study selection

Two authors (JTP, SMG) independently reviewed potential studies according to a set of eligibility criteria. Studies eligible for inclusion had participants (men or women; ≥50 years of age) with a small infrarenal abdominal aortic aneurysm, spanning the baseline diameter range of between 3.0 and <6.0 cm: for some studies this was a subgroup of the total patient group described. At this stage, languages were restricted to English, Spanish, French, Swedish, Danish, and Norwegian (so that data could be extracted by the project team). In addition, review articles, studies where patient data were duplicated (in which case the most recent or comprehensive study was used), non-human studies, editorials, letters, case reports, studies using patients previously treated by AAA surgery or aneurysms of other arteries, and studies reporting on patients with the Marfan syndrome were all excluded.

There was no restriction on either the minimum number of ruptures or the timing when preceding aneurysm diameter measurements were recorded, although small studies of <50 patients recruited over more than 3 years where rupture was not a primary outcome were excluded (because of probable patient selection and publication biases), although this proved never to be the sole reason for exclusion. In addition, study authors were contacted in cases where aneurysms could not easily be separated according to size range of interest. It also was essential that mean length or person-years of follow-up was reported in the eligible studies to calculate rupture rates; if these were not reported authors were contacted.

Data collection process

A data extraction form to identify variables and potential biases in the eligible studies was designed. In particular, the following characteristics were identified: the study design, source of patients, defined intervention policy, method of follow-up, frequency of follow-up, patient recruitment, presence of a mortality review committee, length of follow-up (mean, median or total person-years), inclusion criteria, enrolment date, number of included patients (with more than one ultrasound scan or CT), age, sex, ethnicity, other baseline data (blood pressure, smoking status, drugs, ischaemic heart disease, peripheral artery disease, diabetes), outcomes (number of ruptures, how ruptures were diagnosed, whether ruptures were reported by size band, number of non-rupture deaths, number of AAA repairs, category of professional who carried out aortic measurements), analysis (statistical methods used), author affiliation, date of publication, and country (where study was undertaken). The same two authors (JTP, SMG) independently extracted data from the eligible primary studies and cross-checked their results. Any disagreements between the two reviewers were settled by a third person (LCB).

Any studies that failed to provide essential variables (number of ruptures and length of follow-up) were either rejected or, if the study was published in the previous 15 years (1994–2009), the authors were contacted for this information. If study authors did not respond to the reviewers repeated correspondence, these studies were withdrawn from the selected short list of publications. The reasons for exclusion of studies are shown in Web Appendix II.
Calculation of rupture rates

Rupture rates (per 100 person-years) were calculated from each study by extracting the number of reported ruptures and person-years of follow-up. For studies that reported mean follow-up, person-years were first calculated by multiplying the mean follow-up by the number of patients under surveillance. Any additional surveillance post aortic surgery was not included in the calculation of person-years. Rupture rates were estimated by dividing the number of ruptures by the person-years of follow-up and multiplying by 100. In addition, a small aneurysm rupture rate was calculated if the paper quoted the number of small aneurysm ruptures (last recorded measurement in the range 3.0–5.5 cm) and person-years of follow-up in the small aneurysm range. This required the study to have recorded AAA diameter at regular intervals throughout follow-up, and crucially to have reported conditional follow-up within the diameter range 3.0–5.5 cm. A 95% confidence interval was calculated for each rupture rate by assuming the number of ruptures followed a Poisson distribution.

Results

Identification of relevant studies

A total of 10,160 study titles were identified by the initial search strategy and, of these, 9951 titles were excluded (Fig. 1). In the next step, a total of 209 potential abstracts were reviewed and 54 selected for further review of full-text publications, while 155 were excluded. Of the 54 eligible full-text publications, 40 were excluded due to the following reasons (Web Appendix II): 1. Language (n = 3)\textsuperscript{11–13}; 2. Duplicated patients/data (n = 7)\textsuperscript{12–15}; 3. Modelling, no original data (n = 5)\textsuperscript{19–23}; 4. Person-years follow-up not available (n = 21)\textsuperscript{9,13,20,24–41}; 5. Inaccurate diagnostic criteria of either aneurysm size or rupture (n = 3)\textsuperscript{24,38,42}; 6. Patient selection bias (n = 6)\textsuperscript{32,34,40,42–44}; 7. Ruptures in incorrect size range (n = 11)\textsuperscript{16,22,27,33,36,39,44–48}; 8. Small studies (<50 patients collected over more than 3 years) (n = 4)\textsuperscript{11,43,47,48}; some studies were excluded for more than one reason and some reasons were ascertained by author enquiry\textsuperscript{18} or after statistical review.\textsuperscript{41} A total of 14 eligible studies were identified for inclusion in the systematic narrative review and are shown in Table 1.\textsuperscript{2,49–61}

Data extraction: study characteristics

The 14 included studies were published from 1991 to 2008 (with patients enrolled from 1976 to 2006); 11 of these were prospective studies (including 4 randomised trials), whilst the remaining 3 studies had both retrospective and prospective contributions. Only 5 of the studies had aneurysm rupture as a primary outcome measure\textsuperscript{49,51,55,56,61} and even in these studies the diagnostic criteria for aneurysm rupture were not reported. Overall 9779 patients (8662 men, 1117 women) were included, with study size ranging from 176 to 2257 patients and average length of follow-up ranging from 1.6 to 4.6 years. Most studies used ultrasonography to monitor aortic diameter but some studies used computed tomography (CT) as well as ultrasonography\textsuperscript{51,55–58,61} and one study also used magnetic resonance imaging.\textsuperscript{57} Many studies included patients with aortas <3.0 cm in diameter or with aneurysms >5.5 cm in diameter and for many studies it was not clear whether patients with aortas either <3.0 cm or >5.5 cm were included in the years of follow-up reported. Only 1 study\textsuperscript{59} unambiguously reported conditional follow-up for the diameter range 3.0–5.5 cm, although this could be estimated in 6 further studies. These 7 studies included 5834 patients (86% male). Many studies were more than 10 years old, so that requests to authors for further information met with little success.

The diagnostic criteria for aneurysm rupture were not reported in any study and methods for the ascertainment of rupture were reported in only 2 studies\textsuperscript{2,49}: only these studies and one other\textsuperscript{59} had any independent audit of deaths. One randomised trial\textsuperscript{2} reported 11 ruptures in the surveillance group; however two cases which were reported as being discovered at laparotomy for elective surgery as “a hole in the aortic wall covered by a thin layer of connective tissue, the other as a hole plugged by thrombus”, findings not made on pre-operative imaging. This information was reviewed independently by two Professors of Vascular Surgery: in the absence of information about intramural or extramural haematoma, their decision was that these two cases should not be considered as ruptures for the purposes of this review. Causes of death other than from aneurysm rupture were often not collected systematically and were reported variously, which might have led to under-reporting of aneurysm rupture rates in several studies: only three studies had any independent review of causes of death.\textsuperscript{2,49,61} The mean or median age of patients was reported as between 65 and 75 years in most of the included studies\textsuperscript{2,49–51,53–56,58–61} whilst age was not specified in two
<table>
<thead>
<tr>
<th>Author Year Country</th>
<th>Total number of patients (women) baseline AAA diameter</th>
<th>Total ruptures/total person years</th>
<th>Total small aneurysm ruptures/person years [diameter range for subgroups] (fatal ruptures by 30d or not reported)</th>
<th>Rate of small aneurysm ruptures per 100 person-years (95% confidence interval)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown, 1999 UK</td>
<td>2257 (465) [3.0 to 9.7 cm]</td>
<td>103/4102</td>
<td>67/3215 [3.0-5.9 cm] 27/2600 [3.0-4.9 cm] 40/615 [5.0-5.9 cm]</td>
<td>2.08 (1.62, 2.65) 1.04 (0.68, 1.51) 6.50 (4.65, 8.86)</td>
<td>1. Person years for the 3.0-4.9 size range calculated from number of ruptures / reported rupture rate</td>
</tr>
<tr>
<td>Buckenham, 2007 New Zealand</td>
<td>198 (50) [2.8-7.8 cm]</td>
<td>5/325.05 (Person-years estimated from median follow-up)</td>
<td>3/unknown (3 fatal)</td>
<td>unknown</td>
<td>1. Threshold diameter for surgery in women changed from 5.5 to 5.0 cm in June 2004.</td>
</tr>
<tr>
<td>Brown, 2003 Canada</td>
<td>372 (99) [5.0-5.4 cm]</td>
<td>9/560</td>
<td>9/560 [5.0-5.4 cm]</td>
<td>1.61 (0.73, 3.05)</td>
<td>1. Some patients also may be reported in study Brown 2003a51</td>
</tr>
<tr>
<td>Scott, 2005 England</td>
<td>1333 (0) [3.0-5.4 cm]</td>
<td>36/5465.3</td>
<td>12 / 3110.8 [3.0-5.4 cm]</td>
<td>0.39 (0.20, 0.67)</td>
<td>1. Cause of death only available in 43% of patients</td>
</tr>
<tr>
<td>Brown, 2003 Canada</td>
<td>895 (207) [3.0-4.9 cm]</td>
<td>0/3088</td>
<td>0/3088 [3.0-4.9 cm]</td>
<td>0.00 (0.00, 0.12)</td>
<td>1. Rupture rates calculated from last ultrasound diameter.</td>
</tr>
<tr>
<td>Santilli, 2002 USA</td>
<td>790 (0) [3.0-3.9 cm]</td>
<td>0/3071.32</td>
<td>0/unknown unknown</td>
<td>unknown</td>
<td>1. Cause of death only available in 43% of patients</td>
</tr>
<tr>
<td>Reed, 1997 USA</td>
<td>176(64-69) [&lt;3-&gt;6 cm]</td>
<td>11/862</td>
<td>1/333 [3.0-5.0 cm]</td>
<td>0.30 (0.01, 1.67)</td>
<td>1. Rupture rates calculated from last ultrasound diameter.</td>
</tr>
<tr>
<td>Guirguis, 1991 Canada</td>
<td>300 (89) [2.5-5.0 cm]</td>
<td>14/850</td>
<td>2/unknown unknown</td>
<td>unknown</td>
<td>1. Surveillance group only</td>
</tr>
<tr>
<td>Armstrong, 2007 USA</td>
<td>334 (3) [4.0-5.4 cm]</td>
<td>2/946</td>
<td>2/946 [4.0-5.4 cm] (1 fatal)</td>
<td>0.21 (0.03, 0.76)</td>
<td>1. Surveillance group only</td>
</tr>
<tr>
<td>Vega de Ceniga, 2006 Spain</td>
<td>352* (19) [3.0-5.0 cm]</td>
<td>2/1619</td>
<td>0/unknown unknown</td>
<td>unknown</td>
<td>1. Excluded AAAs enlarging by &lt;2 mm in previous year.</td>
</tr>
<tr>
<td>Laupacis, 2002 Canada</td>
<td>552 (88) [3.0-5.0 cm]</td>
<td>At least 3/1380 At least 2/unknown (&lt;5.5 cm fatal NR 2/3 total ruptures)</td>
<td>unknown</td>
<td>1. Unclear how many person-years are included beyond 5.5 cm</td>
<td></td>
</tr>
<tr>
<td>McCarthy, 2003 England</td>
<td>1423 (0) [2.5-4.0 cm]</td>
<td>2/5045</td>
<td>2/unknown (2 fatal)</td>
<td>unknown</td>
<td>1. Surveillance group only</td>
</tr>
<tr>
<td>Lederle, 2002 USA</td>
<td>567 (5) [4.0-5.4 cm]</td>
<td>11/1833</td>
<td>9/1833 [4.0-5.4 cm] (8 fatal)</td>
<td>0.49 (0.22, 0.93)</td>
<td>2 Covered &quot;hole in wall&quot; at elective repair cases excluded</td>
</tr>
<tr>
<td>Schlosser, 2008 Netherlands</td>
<td>230 (23) [3.0-5.5 cm]</td>
<td>7/755</td>
<td>6/unknown (&lt;5.5 cm fatal NR 6/7 total ruptures)</td>
<td>unknown</td>
<td>2 Covered &quot;hole in wall&quot; at elective repair cases excluded</td>
</tr>
</tbody>
</table>

For many studies the conditional follow-up for aneurysm diameter 3.0-5.5 cm, to aneurysm rupture or death could not be established.
* These studies only included patients with more than 1 scan. NR: not reported
The majority of the studies included both genders, although women were always in a minority. Three population screening studies reported exclusively on male participants. Details of the included studies (e.g., age, inclusion criteria, description of study follow-up and intervention policy, last diameter and time between last diameter and rupture) are summarised in Table 2.

Other characteristics, such as ethnicity, history of smoking, prevalence of diabetes, blood pressure, and other clinical history were not available for all studies.

Extraction of rupture rates

Of the 14 studies reporting on aneurysms in the baseline diameter range 3.0—5.5 cm, rupture rates for aneurysms in the diameter range 3.0—5.5 cm only (conditional follow-up to 5.5 cm diameter, larger aneurysms excluded) could only be estimated from 7 studies, with rupture rates estimated as varying from 0 to 1.61 ruptures/100 person-years (Fig. 2). The studies in the figure are sorted according to the midpoint of the diameter range, and exhibit a slight trend towards higher rupture rates for larger diameters; for example, no ruptures were reported within 12 months of a measurement of <4.0 cm. Nevertheless, the size range only partly explains the considerable heterogeneity between the rupture rate estimates, demonstrated by an $I^2$ value of 89% (i.e., 89% of the total variation is attributable to heterogeneity). Two studies estimate the rupture rate to be greater than 1 rupture/100 person-years, whilst the point estimates from the remaining five studies are all below 0.5 ruptures/100 person-years. Therefore it was decided that, due to the large heterogeneity, a formal synthesis of the results (meta-analysis) was not appropriate.

Rupture rates estimated from total reported ruptures and follow-up (including aneurysms over 5.5 cm) from all 14 studies (details provided in Web Appendix III) ranged from 0 to 2.51 ruptures/100 person-years. In this figure, the studies are sorted according to the midpoint of the baseline diameter range. The between study variation is even more extreme, with an $I^2$ value of 96%.

Discussion

Rupture of an abdominal aortic aneurysm is defined as blood leaking through the aortic wall into the peritoneal or retroperitoneal spaces: the diagnosis of rupture therefore depends on imaging (usually CT), findings at laparotomy or autopsy. A particular constellation of clinical symptoms including circulatory collapse, in the presence of a known aneurysm, also will give rise to the reporting of death from aneurysm rupture without autopsy. Contained or intramural rupture also may occur, when either the leak has sealed spontaneously or the bleeding remained intramural: the intramural blood from these ruptures usually can be detected by CT imaging. In contrast, abdominal or back pain and aortic tenderness in the presence of a known aneurysm does not necessarily imply rupture, although such aneurysms may be repaired urgently and listed as an emergency hospital admission. Very surprisingly none of the eligible studies for this review reported their diagnostic criteria for aneurysm rupture and only 3/14 studies reported the evidence from which a diagnosis of rupture was made. This lack of clarity about the diagnosis of rupture is a major limitation of these studies. In the forthcoming European Society of Vascular Surgery Guidelines for the management of abdominal aortic aneurysms, a clear definition of ruptured aneurysm is provided and hopefully this will be used in future studies: “Abdominal aortic aneurysm rupture is defined as bleeding outside the adventitia of a dilated aortic wall. Rupture is further classified into free rupture in the peritoneal cavity and retroperitoneal rupture where the retroperitoneal tissues provide tamponade and reduce temporarily the volume of blood loss.”

Although many studies report the number of aneurysm ruptures, few studies have length of follow-up information to permit the estimation of rupture rates. Nevertheless there are many more studies, with almost 10,000 patients, describing rupture rates of small aneurysms than were available for a recent systematic review of rupture rates in large aneurysms1 or an earlier review of the surgical management of aneurysms to 1997.63 The review of Hallin et al.64 included only 1160 patients over the entire range of aneurysm diameters, even after relaxation of the original selection criteria relating to study size (originally $n = 50$) and date of patient inclusion. This study only reported the percentage of patients with rupture at 1 and 4 years, rather than rupture rates and the principal comment related to the poor methodology of studies identified. The study of large aneurysms including only 533 patients in total, reported a rupture rate of 10.3 [95% CI 7.5—14.3] per 100 person-years for aneurysms 5—5.9 cm in diameter in those considered unfit for aneurysm repair.7 The rupture rates reported here, for aneurysms of 3—5.5 cm in diameter, are much lower at 0—1.61 per 100 person-years, with a trend for rupture rates to increase with increasing diameter.

Since no study reported the diagnostic criteria for rupture, the evidence from post-mortem studies was examined. There are limited data from post-mortem studies and because the post-mortem diameter is lower than any in vivo measurement, post-mortem data may be unreliable. A prospective autopsy series of 78 aneurysms where the autopsy aorta was subject to pressure inflation at 80—100 mm Hg did not show any ruptures in specimens of $\leq 5.0$ cm.64 This same study reported that without pressure inflation post-mortem diameters were usually smaller than any in vivo measurement, probably by 0.4—0.5 cm or in some cases by almost 50%. Therefore data from the only large scale autopsy series, which reported retrospectively on the rupture of aortic aneurysms in almost 24,000 consecutive autopsies at the Massachusetts General Hospital in the period 1952—1975 is unreliable.65

The studies reported in this review have patients with disparate ranges of aortic diameter as well as intervention and follow-up policies and these are likely to be important reasons for the heterogeneity observed. Gender is another important reason likely to contribute to the heterogeneity, since rupture rates of small aneurysms have been reported as being 3—4 fold higher in women.1,49,51 There are numerous other reasons likely to influence heterogeneity too, such as inclusion and exclusion criteria for the different studies, method of aneurysm sizing (including whether internal or external diameters were recorded), censoring and...
<table>
<thead>
<tr>
<th>Study</th>
<th>Inclusion criteria (aortic diameter ranges)</th>
<th>Age (years) of participants (mean)</th>
<th>Surveillance policy</th>
<th>Intervention policy*</th>
<th>Ascertainment of rupture/time between last diameter &amp; rupture</th>
<th>Rupture rates as published</th>
</tr>
</thead>
<tbody>
<tr>
<td>49P Brown</td>
<td>AAA: &gt;3 cm 3.0-3.9; 4.0-5.5; 5.6-9.7 cm</td>
<td>70</td>
<td>US, 4-4.9 cm: 6 mo; 5.5-5.5 cm: 3 mo</td>
<td>&gt;5.5 cm</td>
<td>Yes/Yes</td>
<td>Annual rupture rate: 2.2% (95% CI 1.7-2.8); large and small aneurysms</td>
</tr>
<tr>
<td>50PR Buckenham</td>
<td>AAA: 3-5.5 cm; fit for surgery 2.8-7.8 cm</td>
<td>73 **</td>
<td>US, varied with gender and size</td>
<td>Men &gt;5.5 cm Women &gt;5.0 cm</td>
<td>No/No</td>
<td>1% per year (men); 3.9% per year (women); large and small aneurysms</td>
</tr>
<tr>
<td>51P Brown</td>
<td>AAA: 5-5.9 cm, unfit for surgery</td>
<td>73</td>
<td>US, 6-monthly</td>
<td>all patients unfit for surgery</td>
<td>No/No</td>
<td>36 per 1000 person-years [95%CI 15-75] for those with AAA &gt;5.5 cm at recall No ruptures</td>
</tr>
<tr>
<td>52P Scott</td>
<td>AAA: 3-5.5 cm men 65-74 yrs</td>
<td>NR</td>
<td>US, 3.4-4.4: yearly; 4.5-5.4: 3-monthly</td>
<td>5.5 cm</td>
<td>No/No</td>
<td>No ruptures</td>
</tr>
<tr>
<td>53P Brown</td>
<td>AAA: 3.0 to 5.0 cm</td>
<td>69</td>
<td>US, CT, 6-monthly</td>
<td>NR</td>
<td>No/-</td>
<td>No ruptures</td>
</tr>
<tr>
<td>54P Santilli</td>
<td>AAA: 3-3.9 cm</td>
<td>69</td>
<td>US, variable.</td>
<td>NR</td>
<td>No/-</td>
<td>No ruptures</td>
</tr>
<tr>
<td>55P Reed</td>
<td>AAA not for surgery &lt;3 to ≥8 cm</td>
<td>74</td>
<td>US, NR</td>
<td>NR</td>
<td>Yes/Yes</td>
<td>By last diameter: 3-3.99 cm: 0 ruptures/PY; 4-4.99 cm: 0.007 ruptures/PY; 5-5.99 cm: 0.11 ruptures/PY</td>
</tr>
<tr>
<td>56PR Guirgius</td>
<td>AAA initially managed non-operatively 2.5-9.3 cm</td>
<td>70</td>
<td>US, CT 6-monthly</td>
<td>NR</td>
<td>No/No</td>
<td>Cumulative incidence only reported</td>
</tr>
<tr>
<td>57PR Armstrong</td>
<td>AAA: 4-5.4 cm</td>
<td>NR</td>
<td>US, CT, MRI 3-4 cm: yearly; 4.5-5.4 cm: biannually</td>
<td>&gt;5.4 cm</td>
<td>No/No</td>
<td>NR</td>
</tr>
<tr>
<td>58P Vega de Ceniga</td>
<td>AAA: 3-4.9 cm</td>
<td>71</td>
<td>US: yearly if &lt;4 cm; CT: every 6 mo</td>
<td>&gt;5.0 cm</td>
<td>No/No</td>
<td>NR</td>
</tr>
<tr>
<td>59P Laupacis</td>
<td>AAA: 3-5.0 cm; no contraindications to propranolol aortas: 2.6-3.9 cm</td>
<td>69</td>
<td>US, 6-monthly</td>
<td>Variable, &gt;4.5 cm or &gt;5.0 cm by centre</td>
<td>No/No</td>
<td>NR</td>
</tr>
<tr>
<td>60P Macarthy</td>
<td>US, 2.6-3.9: yearly; 4.0 cm: 6-monthly</td>
<td>65</td>
<td>&gt;5.5 cm</td>
<td>No/Yes</td>
<td>2-yr rupture rate: 1.4% (3.5-3.9 cm group, 0% at 3 yrs for smaller aortas Less than 0.6% per year of follow-up of unrepaiired aneurysms</td>
<td></td>
</tr>
<tr>
<td>61P Schlosser</td>
<td>AAA: 3-5.5</td>
<td>66</td>
<td>US, 3-3.9 cm: yearly; 4.5-5.5 cm: 6-monthly</td>
<td>&gt;5.5 cm</td>
<td>No/No</td>
<td>0.9% per person-year, including aneurysms &gt;5.5 cm</td>
</tr>
</tbody>
</table>

* Elective repair is contingent on patient fitness and consent; in addition most studies reported being willing to repair the aneurysm for aneurysm-related symptoms and rapid growth (>1 cm/y); US ultrasound, CT computed tomography, MRI magnetic resonance imaging, NR not reported, P prospective study, R retrospective study, PR prospective and retrospective contributions, PY person-year. ** To link with age 73 above median age reported.
inadequate reporting of cause of death. Many of the included studies recruited patients more than 15 years ago, so that improvements in the medical therapy of these patients may be an added reason for the high heterogeneity observed.

Both the PIVOTAL and CAESAR trials of endovascular repair versus surveillance for small aneurysms reported in 2010 after the search for this review closed.3,66 In the PIVOTAL trial the rupture rate in the surveillance was 0.17 per 100 patient years (although this includes some follow-up after aneurysm repair, which occurred in 31%) and in the CAESAR trial, although mean conditional follow-up was not reported, the rupture rate appears to be <1 per 100 person-years. These are in keeping with the results reported here.

A new large prospective study based on population screening would be the most robust method of assessing the rupture rates of small aneurysms in the 21st century. Such a study would take time to set up and several years of follow-up before it could report. For now, an alternative way to assess the rupture rates of small aneurysms would be through synthesis of a large amount of individual patient data from relevant studies. This is the strategy we are pursuing, even though it will be hampered by the poor definition of aneurysm rupture in most studies. Additional studies, particularly those following patients in the 21st century, would be very welcome for this individual patient data meta-analysis of the rupture rate of small aneurysms.

Conclusion

The rupture rate of small abdominal aortic aneurysms (3.0–5.5 cm diameter) appears to lie between 0 and 1.61 per 100 person-years but the studies are very heterogeneous and suffer from absence of clear reporting standards for aneurysm rupture.

Conflict of Interest

None.

Author Contributions

All critical review and approval of the manuscript; LCB Data extraction & statistical evaluation of potentially eligible studies; FGRF review & approval of protocol, SG review of titles, abstracts & papers, data extraction, maintaining references; JTP review of abstracts & papers, data extraction, drafting review; MJS Data extraction & statistical evaluation of potentially eligible studies; SGT direction & overview.

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Appendix

Supplementary data

Supplementary data associated with this article can be found in the on-line version, at doi:10.1016/j.ejvs.2010.09.005.

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