

Eur J Vasc Endovasc Surg 35, 558–570 (2008)

doi:10.1016/j.ejvs.2007.11.019, available online at <http://www.sciencedirect.com> on 

## REVIEW

## Meta Analysis on Mortality of Ruptured Abdominal Aortic Aneurysms

L.L. Hoornweg,<sup>1</sup> M.N. Storm-Versloot,<sup>1</sup> D.T. Ubbink,<sup>2</sup> M.J.W. Koelemay,<sup>1,3</sup>  
D.A. Legemate<sup>1</sup> and R. Balm<sup>1\*</sup>

Departments of <sup>1</sup>Vascular surgery, <sup>2</sup>Clinical Epidemiology, Biostatistics and Bioinformatics, Academic Medical Center, Amsterdam, The Netherlands, and <sup>3</sup>Department of Surgery, Tergooi Hospitals, Hilversum, The Netherlands

**Objectives.** To assess the mortality of patients with ruptured abdominal aortic aneurysms undergoing open surgery and examine changes in mortality over time.

**Methods.** Literature databases were searched for relevant articles published between 1991 and 2006. Two reviewers independently performed study inclusion and data extraction. Primary outcome measure was 30 day or in-hospital mortality. Subgroup analyses were performed examining the effect of population- and hospital-based studies, hospital volume and type of surgeon.

**Results.** From a total of 1419 identified studies, 145 observational studies met the inclusion criteria of which 116 were included in the systematic review comprising 60,822 patients. Overall mortality was 48.5% (95% CI: 48.1–48.9%) and did not change significantly over the years. Age increased over the years. For overall mortality a trend was seen in favour of high-volume hospitals.

**Conclusions.** This meta-analysis suggests that mortality of patients with RAAA treated by open surgery has not changed over the past 15 years. This could be explained by increased age of patients undergoing RAAA repair.

© 2007 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.

**Keywords:** Meta-analysis; Ruptured abdominal aortic aneurysm; Surgery; Mortality.

## Introduction

The incidence of ruptured abdominal aortic aneurysms (RAAA) is 5.6–17.5 per 100,000 person-years in Western countries<sup>1–3</sup> and the overall mortality rate of patients with a RAAA is approximately 80–90%.<sup>1,4,5</sup> Hence RAAA signifies an important cause of death, which may further increase as the population ages. The only therapeutic option for patients with RAAA is emergency open or endovascular surgery.

Despite considerable improvements in emergency care, diagnostic facilities, anaesthesiology and intensive care, mortality rates of RAAA repair have stayed

more or less the same over time, and are still reported to be as high as 40% to 50%.<sup>6–12</sup> However, in a meta-analysis Bown *et al.* suggested a slight decrease in operative mortality from 1954 to 1997.<sup>13</sup> A review reporting on more recent studies is lacking.

Several studies have shown a discrepancy in outcome of RAAA between national and hospital registries, with better outcome in the latter.<sup>14–16</sup> Hospital volume also might influence outcome of RAAA, but reports on mortality in patients with RAAA in high and low volume centers remain contradicting.<sup>17–19</sup>

The aim of the present study was to perform a systematic review of recent literature on mortality in patients with RAAA treated with open surgery and examine changes in mortality over time. In addition we evaluated the concordance of national registries with hospital registries, and explored the effect of age, hospital-volume and type of surgeon on mortality rates.

\*Corresponding author. R. Balm, MD, PhD, Academic Medical Center G4-107, Meibergdreef 9, 1105 AZ Amsterdam, P.O. Box 22700, 1100 DE Amsterdam, The Netherlands.  
E-mail address: [r.balm@amc.nl](mailto:r.balm@amc.nl)

## Methods

### *Search strategy*

Electronic literature searches were performed by two independent investigators using Pubmed, Medline, Embase, Sumsearch, Cinahl, The Cochrane Central Register of Controlled Trials and Excerpta Medica. While aiming to obtain the most recent articles and bearing in mind a previous meta-analysis which included studies up to 2000,<sup>13</sup> we restricted our search to the studies published after 1991. The search strategy used for each database is described in the [Appendix](#). In addition, we manually searched the reference lists of relevant articles to identify articles missed by electronic searches. Language was restricted to English, German, French, Spanish and Dutch. We did not systematically search abstract books of conference proceedings, did not hand search leading journals, and did not contact leading authors in the field to retrieve potential extra papers.

### *Inclusion and exclusion criteria*

#### *Types of studies*

Any prospective or retrospective studies evaluating mortality of conventional surgical treatment in patients with RAAA were considered. Studies had to describe an original patient series. In case series reported on more than one occasion the report with the most complete information on outcomes was included. Studies had to comprise a minimal number of forty patients and to describe a consecutive patient series to be eligible for inclusion.

#### *Types of participants*

Studies were eligible if they defined a RAAA as the presence of blood outside the aortic wall diagnosed by ultrasound or computed tomography (CT), or confirmed during surgery, and we included articles if investigators clearly distinguished RAAA from symptomatic abdominal aortic aneurysms. Studies reporting on thoracic, inflammatory or mycotic aneurysms were excluded. Also studies reporting solely on subgroups, such as octogenarians, were excluded to prevent confounding on mortality rates by age.

#### *Types of intervention*

Treatment of patients with surgery had to be described in the studies. No restrictions were made with respect to the operative technique, which was either trans- or retroperitoneal.

#### *Types of outcome measures*

At least one of the following primary outcome measures had to be reported: intra-operative (during operation), or overall mortality rates (30 day or in-hospital, i.e. procedure related). Secondary outcome measures were: hospital volume (mean number of RAAA operations yearly per hospital), type of surgeon (general or vascular) and hospital-based studies or population-based (data from national or regional registries).

#### *Study selection*

After identifying relevant titles, the corresponding abstracts were judged independently by two reviewers (LH and MNSV). If disagreement occurred, the final decision regarding inclusion was based on the full article. Any discrepancies on article selection were resolved by discussion or a third reviewer (MK).

### *Methods of the meta-analysis*

#### *Study quality and data extraction*

Two reviewers (LH and MSV) extracted the data independently. The data collected from each study included (1) the mid-time point of the study (the date half way through the inclusion period), (2) country of origin, (3) patient characteristics (total number of patients operated on, mean or median age, sex) and (4) intra-operative and overall mortality rates. If possible, we noted the number of patients who died before a surgical intervention.

We applied the guidelines for meta-analysis of observational studies in epidemiology (MOOSE).<sup>20</sup>

#### *Statistical analysis*

Meta-regression analysis was performed for intra-operative as well as overall mortality rates. Both outcomes were used in a regression model plotted against time and weighted by study size. Funnel plots were made to explore potential publication bias for mortality rates. Data were analyzed using SPSS Version 12.0.2 (SPSS Inc., Chicago, Illinois, USA).

## Results

The search identified 1419 potentially eligible studies of which 1119 were excluded based on title and abstract. From the remaining 300 studies full articles were collected and re-evaluated. One hundred forty-five articles satisfied our inclusion criteria. Study flow and reasons for exclusion are presented in [Fig. 1](#). Twenty-nine articles reported on similar databases, resulting in 116 articles to be included in the

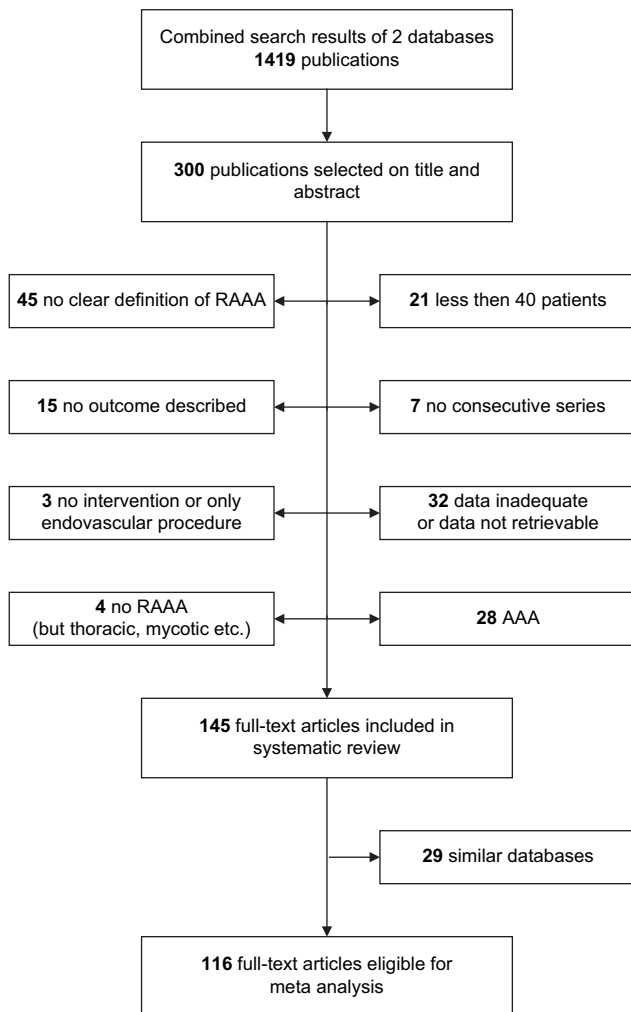


Fig. 1. Study flow and exclusion criteria.

systematic review. Agreement on inclusion of these full articles resulted in a good kappa value of 0.78.<sup>21</sup>

#### Study descriptions

Characteristics of the included articles are shown in Table 1. These articles represented 60,822 patients undergoing surgery for RAAA over a period of 33 years (mid time point of studies between 1970 and 2003). One hundred fifteen articles reported in-hospital or 30-day mortality rates, one article exclusively reported on intra-operative mortality. A total of 37 articles reported intra-operative mortality rates. The number of patients that died before surgery was reported in 24 articles. Mean age was described in 58 articles and distinction between gender was made in 67 articles. Sixty nine articles allowed for calculation of the number of operated patients per year per hospital.

Type of surgeon was specified in 4 articles and 20 articles reported data originating from a national registry. Only 17 studies were prospective, 52 studies were retrospective and 47 articles failed to describe the study design.

#### Meta analysis

##### Mortality

The weighted mean overall mortality was 48.5% (95% CI: 48.1–48.9%). Fig. 2 shows crude overall mortality rates per year from 1991 onwards. For 37 studies reporting intra-operative mortality, the weighted mean was 13.3% (95% CI: 12.3–14.3%).

##### Metaregression analysis

For overall mortality metaregression analysis showed a reduction of 1.6% over 33 years which was not significant ( $p = 0.84$ , Fig. 3). For intra-operative mortality rates the metaregression is shown in Fig. 4. The regression suggested an increase of 1.2% in 29 years, which was not significant over time ( $p = 0.69$ ).

Metaregression analysis on the 58 articles reporting on age demonstrated a significant change of age over time ( $p = 0.03$ , Fig. 5). Metaregression analysis for the subgroup of 58 studies describing the number of RAAA repairs carried out per year (Fig. 6) demonstrated a positive association between hospital volume and overall mortality rates ( $p = 0.04$ ). Although the mortality rates decrease as the hospital volume increases, we have to consider the wide 95% confidence interval. Very few centers performed more than 30 RAAA repairs per year.

There was no significant difference in overall mortality presented in articles retrieving data from national registries and articles retrieving data from hospital records (mean difference 2.1%; 95% CI –6.9 to 2.8%;  $p = 0.4$ , Wilcoxon test).

Only 4 articles discerned precisely the subspecialty of the operating surgeon, making any analysis meaningless.<sup>22–25</sup> A considerable difference was observed for studies of different design. The pooled overall mortality for prospective studies was 46.7% (95% CI: 36.7–56.7%) versus 41.1% (95% CI: 32.5–49.7%) for retrospective studies ( $P = 0.03$ ). However the subgroup of prospective studies was relatively small which makes interpretation difficult.

##### Assessment of publication bias

A funnel plot was performed for all 115 studies reporting on overall mortality to detect publication bias (Fig. 7). Asymmetry in a funnel plot often indicates publication bias. Since data were symmetrically

**Table 1. Study characteristics**

Author	Midpoint of study	Year of publication	Country of origin	Mean age (yrs)	Women N (%)	Patients operated N	Diseased before operation N	Overall mortality N (%)	Peroperative mortality N (%)	RAAA per year	Registry	Type of surgeon	Study design
Drott C <sup>24</sup>	1970	1992	Sweden	71	nr	184	nr	96(52,2)	nr	nr	Yes	gen/vas	nr
Chen JC <sup>31</sup>	1974	1997	Canada	nr	71(16)	436	nr	195(44,7)	nr	11	No	nr	retro
Thevenet A <sup>32</sup>	1974	1991	France	nr	nr	134	nr	65(48,5)	20(14,9)	5	No	vasc	nr
Ghilardi C <sup>33</sup>	1978	1993	Italy	nr	nr	373	nr	130(34,9)	nr	nr	No	nr	nr
Trotter MC <sup>34</sup>	1978	1992	USA	nr	nr	45	3	21(46,7)	nr	11	No	vasc	retro
Poulias GE <sup>35</sup>	1980	1994	Greece	nr	nr	80	nr	33(41,3)	nr	nr	No	vasc	nr
Jaakkola P <sup>36</sup>	1980	1996	Finland	67	4(8)	48	nr	31(64,6)	nr	5	No	nr	nr
Bonamigo TP <sup>37</sup>	1981	1991	Brasilia	70	3(6)	50	nr	27(54,0)	4(8,0)	3	No	nr	nr
Soisalon-Soininen S <sup>38</sup>	1981	1999	Finland	nr	55(15)	363	nr	179(49,3)	62(17,1)	17	No	vasc	retro
Cohen JR <sup>39</sup>	1982	1991	USA	82	8(11)	70	nr	47(67,1)	nr	5	No	nr	retro
Cheng SWK <sup>40</sup>	1982	1994	China	nr	nr	61	7	28(45,9)	2(3,3)	4	No	nr	retro
Albes JM <sup>41</sup>	1982	1991	Germany	69	11(8)	142	2	65(45,8)	nr	12	No	vasc	retro
Reitsma JB <sup>42</sup>	1982	1996	Netherlands	ns	ns	2675	nr	1177(44,0)	ns	nr	Yes	nr	retro
Prager M <sup>43</sup>	1983	2000	Austria	nr	21(12)	172	nr	nr	12(7,0)	nr	No	nr	nr
Chafke N <sup>44</sup>	1983	1995	France	nr	nr	45	nr	18(40,0)	nr	nr	No	vasc	retro
Stonebridge PA <sup>45</sup>	1984	1993	UK	71	45(20)	227	nr	61(26,9)	nr	20	No	vasc	retro
McCready RA <sup>46</sup>	1984	1993	USA	70	32(16)	206	2	101(49,0)	39(18,9)	20	No	vasc	retro
Ruberti U <sup>47</sup>	1984	1991	Italy	nr	nr	314	nr	113(36,0)	nr	nr	No	vasc	nr
Johansen K <sup>48</sup>	1984	1991	USA	75	nr	180	6	124(68,9)	25(13,9)	20	No	vasc	retro
Giorgetti PL <sup>49</sup>	1984	1991	Italy	nr	nr	70	nr	34(48,6)	nr	8	No	vasc	nr
Gloviczki P <sup>25</sup>	1984	1992	USA	nr	nr	214	17	89(41,6)	40(18,7)	21	No	gen/vas	retro
Skov Olsen P <sup>50</sup>	1984	1991	Denmark	nr	nr	218	nr	81(37,2)	nr	24	No	vasc	retro
Hans SS <sup>51</sup>	1985	1993	USA	nr	nr	45	nr	21(46,7)	5(11,1)	nr	No	vasc	retro
Scott A <sup>52</sup>	1985	1992	England	nr	8(12)	66	nr	19(28,8)	3(4,6)	nr	No	nr	retro
Aburahma AF <sup>53</sup>	1985	1991	USA	72	8(11)	73	5	45(61,6)	nr	nr	No	nr	retro
Katz DJ <sup>18</sup>	1985	1994	USA	nr	nr	1829	nr	910(49,8)	nr	np	Yes	nr	nr
Samy AK <sup>54</sup>	1985	1994	Scotland	nr	485(25)	1941	rep	1062(54,7)	nr	nr	Yes	nr	nr
Bradbury AW <sup>55</sup>	1986	1998	Scotland	nr	119(18)	673	nr	249(37,0)	67(10,0)	32	No	vasc	pros
Farooq MM <sup>56</sup>	1986	1996	USA	72	16(13)	124	nr	63(50,8)	14(11,3)	10	No	vasc	retro
Panneton JM <sup>57</sup>	1986	1995	Canada	72	15(13)	112	nr	51(45,5)	15(13,4)	9	No	vasc	retro
Ramo OJ <sup>58</sup>	1986	1995	Finland	69	1(2)	43	nr	18(41,9)	nr	4	No	vasc	nr
Miani S <sup>59</sup>	1986	1994	Italy	68	nr	388	nr	124(32,0)	nr	35	No	vasc	nr
Gosselin C <sup>60</sup>	1986	1991	Canada	73	14(14)	80	nr	36(45,0)	nr	12	No	vasc	retro
Dongen van HPA <sup>61</sup>	1986	1998	Netherlands	71	35(11)	309	nr	78(25,2)	nr	22	No	vasc	retro
Rosenthal D <sup>62</sup>	1986	1992	USA	72	7(15)	47	nr	20(42,5)	7(14,9)	8	No	vasc	retro
Johnston KW <sup>63</sup>	1986	1994	Canada	72	20(14)	147	nr	74(50,3)	nr	nr	Yes	nr	nr
Katz SG <sup>64</sup>	1987	1994	USA	73	14(14)	99	nr	56(56,6)	nr	nr	No	nr	retro
Cormier F <sup>65</sup>	1987	1993	France	nr	nr	69	nr	31(44,9)	nr	12	No	nr	nr
Imig H <sup>66</sup>	1988	1996	Germany	nr	nr	224	nr	109(48,7)	29(13,0)	16	No	vasc	nr
Henderson A <sup>67</sup>	1988	1995	Australia	70	19(19)	101	nr	29(28,7)	nr	20	No	vasc	pros
Slootmans FC <sup>68</sup>	1988	1994	Netherlands	72	11(14)	83	nr	39(49,4)	9(11,4)	17	No	vasc	retro

(continued on next page)

Table 1 (continued)

Author	Midpoint of study	Year of publication	Country of origin	Mean age (yrs)	Women N (%)	Patients operated N	Diseased before operation N	Overall mortality N (%)	Peroperative mortality N (%)	RAAA per year	Registry	Type of surgeon	Study design
Magee TR <sup>69</sup>	1988	1992	UK	nr	nr	77	nr	27(35,0)	nr	nr	No	nr	nr
Tromp Meesters RC <sup>70</sup>	1988	1994	Netherlands	70	9(8)	113	nr	60(53,1)	11(9,7)	16	No	nr	retro
Boccara G <sup>71</sup>	1988	1994	France	68	nr	43	nr	14(32,6)	7(16,2)	7	No	nr	retro
Manheim LM <sup>19</sup>	1988	1998	USA	nr	1236(17)	7327	nr	3510(47,9)	nr	np	Yes	nr	nr
Martinez R <sup>72</sup>	1989	1997	France	74	9(11)	84	nr	48(57,1)	18(23,4)	8	No	vasc	retro
Satta J <sup>73</sup>	1989	1997	Finland	69	5(10)	51	nr	24(47,0)	nr	9	No	nr	retro
Koskas F <sup>74</sup>	1989	1997	France	73	16(10)	158	nr	73(46,2)	31(19,6)	nr	No	nr	pros
Callam MJ <sup>75</sup>	1989	1991	UK	nr	nr	74	26	26(35,1)	9(12,2)	56	No	vasc	pros
Bohmer RD <sup>76</sup>	1989	1999	N Zealand	nr	nr	115	nr	60(52,2)	nr	nr	No	nr	retro
Vliet vd JA <sup>77</sup>	1989	1996	Netherlands	nr	nr	44	nr	21(47,7)	nr	11	No	nr	nr
Seiwert AJ <sup>78</sup>	1989	1995	USA	72	12(10)	119	nr	54(45,4)	nr	17	No	nr	retro
Szostek M <sup>79</sup>	1989	1993	Poland	nr	12(6)	211	nr	127(60,2)	nr	nr	No	vasc	retro
Lawrence PF <sup>80</sup>	1989	1999	USA	76	2208(33)	6623	1847	4517(68,2)	nr	nr	Yes	nr	nr
Semmens JB <sup>81</sup>	1989	1998	Australia	nr	nr	283	590	102(36,0)	nr	nr	Yes	nr	nr
Eliason JL <sup>82</sup>	1989	2005	USA	73	3248(20)	15,922	nr	7245(45,5)	nr	nr	Yes	nr	nr
Jarvinen O <sup>83</sup>	1990	1996	Finland	nr	nr	102	nr	55(53,9)	nr	17	No	nr	retro
Roddy SP <sup>84</sup>	1990	2003	USA	nr	66(20)	323	nr	93(28,8)	nr	16	No	vasc	retro
Choksy SA <sup>23</sup>	1990	1999	England	nr	nr	59	78	30(50,9)	nr	7	No	gen/ vas	retro
Bradbury AW <sup>85</sup>	1990	1995	UK	70	nr	60	5	25(41,7)	12(20,0)	12	No	vasc	retro
Bjorck M <sup>86</sup>	1990	1996	Sweden	nr	nr	563	nr	216(38,3)	nr	nr	Yes	nr	nr
Rutledge R <sup>87</sup>	1990	1996	USA	72	307(21)	1480	nr	813(54,9)	nr	nr	Yes	nr	nr
Wu Wen S <sup>9</sup>	1990	1996	Canada	nr	205(17)	1203	nr	481(34,8)	nr	nr	Yes	nr	nr
Akkersdijk GJM <sup>6</sup>	1990	1994	Netherlands	nr	nr	709	nr	309(43,6)	nr	np	Yes	nr	nr
Teufelsbauer H <sup>88</sup>	1991	2003	Austria	73	28(12)	230	nr	92(40,0)	nr	nr	No	nr	nr
Akkersdijk GJ <sup>89</sup>	1991	1998	Netherlands	74	nr	83	14	38(45,8)	nr	17	No	nr	retro
Thorban S <sup>90</sup>	1991	2003	Germany	73	20(15)	132	nr	55(41,7)	nr	7	No	vasc	retro
Evans SM <sup>91</sup>	1992	1999	UK	nr	nr	497	nr	193(38,8)	nr	nr	No	nr	pros
Adam DJ <sup>92</sup>	1992	1999	Scotland	nr	nr	340	632	138(40,6)	nr	nr	Yes	nr	pros
Dardik A <sup>7</sup>	1992	1998	USA	72	108(20)	527	nr	250(47,4)	nr	np	Yes	nr	nr
Kantonen I <sup>17</sup>	1992	1997	Finland	nr	nr	454	nr	209(46,0)	nr	np	Yes	nr	nr
Pfeiffer T <sup>93</sup>	1993	2000	Germany	nr	nr	45	nr	16(35,6)	nr	6	No	nr	nr
Lazarides MK <sup>94</sup>	1993	1997	Greece	72	3(8)	40	nr	22(55,0)	5(12,5)	13	No	vasc	nr
Vammen S <sup>95</sup>	1993	2000	Denmark	nr	nr	99	nr	35(35,4)	nr	nr	No	vasc	retro
Turton EPL <sup>96</sup>	1993	2000	UK	79	32(31)	102	nr	54(52,9)	nr	15	No	vasc	retro
Levison JA <sup>97</sup>	1993	1999	USA	74	13(13)	43	nr	22(51,1)	5(11,6)	5	No	vasc	retro
Sandison AJF <sup>98</sup>	1993	1998	UK	nr	nr	49	nr	16(32,7)	6(12,2)	nr	No	vasc	pros
Sebesta P <sup>99</sup>	1993	1998	Czech Rep	70	11(11)	103	nr	58(56,3)	7(6,8)	15	No	vasc	nr
Heikkinen M <sup>100</sup>	1993	2002	Finland	70	25(15)	166	nr	84(50,6)	nr	16	No	nr	nr
Kazmers A <sup>101</sup>	1993	2001	USA	nr	nr	427	nr	195(45,7)	nr	nr	Yes	nr	nr
Janczyk RJ <sup>102</sup>	1994	2004	USA	74	30(30)	100	38	47(47,0)	nr	10	No	nr	retro
Podlaha J <sup>103</sup>	1994	2000	Czech Rep	71	19(21)	92	nr	44(47,8)	nr	9	No	nr	nr
Artigues I <sup>104</sup>	1994	2000	Spain	72	3(6)	49	6	30(61,2)	nr	10	No	vasc	retro
Alric P <sup>105</sup>	1995	2003	France	73	11(14)	77	nr	20(26,0)	3(3,9)	7	No	nr	nr
Burger T <sup>106</sup>	1995	1999	Germany	70	nr	52	nr	19(36,5)	nr	10	No	vasc	retro
Fichtner-Feigl S <sup>107</sup>	1995	2003	Germany	72	8(17)	46	6	20(43,5)	nr	5	No	nr	nr

Alonso-Perez M <sup>108</sup>	1995	1999	Spain	80	13(12)	112	nr	70(62,5)	8(7,1)	nr	No	vasc	retro
Stone PA <sup>109</sup>	1995	2005	USA	72	17(20)	84	nr	37(44,0)	nr	6	No	nr	retro
Markovic M <sup>110</sup>	1996	2004	Serbia	67	39(17)	229	nr	123(53,7)	31(13,5)	nr	No	vasc	nr
Kessler U <sup>111</sup>	1996	2002	Germany	72	17(20)	85	nr	32(37,7)	11(12,9)	nr	No	nr	nr
Alonso-Perez M <sup>112</sup>	1996	2001	Spain	71	12(8)	144	nr	68(47,2)	25(17,3)	nr	No	nr	retro
Robinson J <sup>113</sup>	1996	2000	UK	73	11(14)	77	nr	34(44,2)	nr	nr	No	nr	pros
Adam DJ <sup>114</sup>	1996	1999	Scotland	74	8(20)	40	nr	20(50,0)	8(20,0)	20	No	nr	pros
Basnyat PS <sup>22</sup>	1996	1999	UK	nr	nr	133	100	85(63,9)	31(23,3)	nr	No	gen/ vas	pros
May J <sup>115</sup>	1997	2004	Australia	73	27(31)	88	3	49(55,7)	8(9,1)	66	No	vasc	nr
Poscioglu H <sup>116</sup>	1997	2002	Turkey	68	1(2)	56	nr	24(42,9)	nr	8	No	vasc	retro
Axelrod DA <sup>117</sup>	1997	2001	USA	69	0(0)	52	nr	16(30,8)	nr	nr	Yes	nr	nr
Pai M <sup>118</sup>	1997	2002	UK	nr	nr	214	nr	112(52,3)	nr	43	No	vasc	pros
Harris JR <sup>119</sup>	1997	2005	Canada	73	32(24)	136	nr	62(45,6)	nr	28	No	vasc	retro
Cheng SW <sup>120</sup>	1998	2003	China	nr	67(36)	194	nr	136(70,0)	nr	nr	Yes	nr	nr
Tambyraja AL <sup>121</sup>	1998	2003	Scotland	nr	nr	273	nr	117(42,9)	nr	39	No	vasc	pros
Vogel TR <sup>122</sup>	1998	2005	USA	nr	11(21)	52	nr	35(67,3)	nr	7	No	nr	retro
Treska V <sup>123</sup>	1998	2006	Czech Rep	72	23(13)	182	nr	61(33,5)	nr	13	No	nr	retro
Pei Ho <sup>124</sup>	1998	2006	China	75	nr	63	15	27(42,9)	nr	5	No	vasc	pros
Wozniak W <sup>125</sup>	1999	2006	Poland	69	9(12)	77	nr	41(53,2)	nr	8	No	nr	pros
Hechelhammer L <sup>126</sup>	2000	2005	Switzerland	nr	nr	52	nr	18(34,6)	nr	9	No	vasc	nr
Boyle JR <sup>127</sup>	2001	2003	UK/ Australia	nr	nr	79	21	26(32,9)	nr	nr	No	vasc	pros
Arya N <sup>128</sup>	2001	2006	UK	77	7(21)	41	nr	24(59,0)	nr	21	No	vasc	retro
Greco G <sup>129</sup>	2001	2006	USA	nr	nr	5508	nr	2627(47,7)	nr	nr	Yes	nr	nr
Tambyraja AL <sup>130</sup>	2003	2005	UK	nr	nr	62	18	25(40,3)	11(17,7)	34	No	vasc	pros
Davies MJ <sup>131</sup>	nr	1993	UK	nr	nr	43	3	15(34,9)	5(11,6)	nr	No	vasc	pros
Nicholls SC <sup>132</sup>	nr	1998	USA	73	nr	161	nr	107(66,5)	nr	16	No	vasc	nr
Maziak DE <sup>133</sup>	nr	1997	Canada	73	19(22)	88	nr	35(39,8)	9(10,2)	18	No	vasc	retro
Piotrowski JJ <sup>134</sup>	nr	1996	USA	nr	nr	101	nr	51(50,5)	nr	14	No	nr	retro
Gordon AC <sup>135</sup>	nr	1993	UK	nr	nr	91	nr	35(38,5)	nr	30	No	nr	retro
Browning NG <sup>136</sup>	nr	1995	South Africa	67	6(13)	49	5	22(44,9)	nr	5	No	vasc	retro

nr: Not reported.

ns: Not possible to retrieve data.

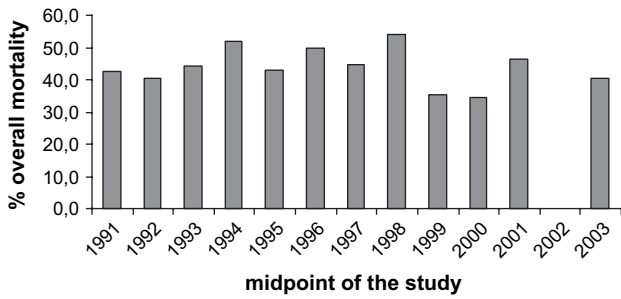


Fig. 2. Overall mortality estimates per midpoint of study.

spread around the vertical axis (representing mean % overall mortality), no publication bias was apparent. We also performed a funnel plot for 37 studies reporting on intra-operative mortality (Fig. 8). This demonstrated publication bias as the plot was asymmetrical.

**Discussion**

The aim of this study was to evaluate mortality in patients with RAAA undergoing open surgery and examine changes over time. In articles published over the last 15 years an overall mortality of 49% was reported. No significant change over time could be demonstrated. In contrast, Bown *et al.*<sup>13</sup> reported a decrease in mortality rate estimates of 55% in 1960 to 41% in 2000. This can be explained by the inclusion of relatively old studies. Their review reports on

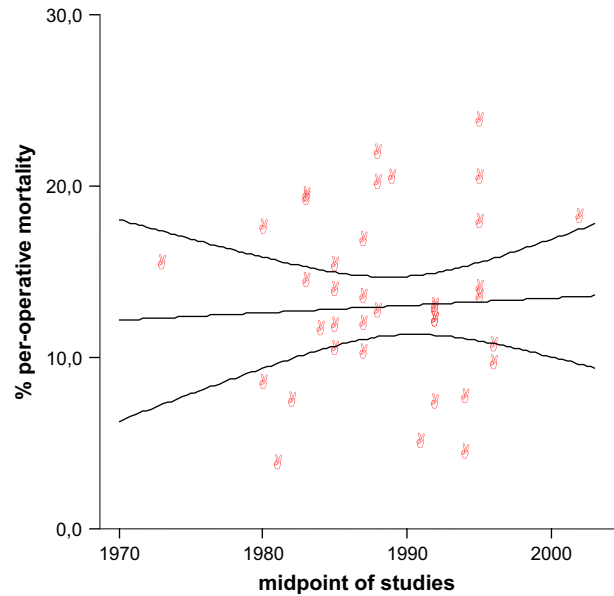


Fig. 4. Meta regression of 37 studies reporting on % per-operative mortality (Y axis) against midpoint of the study (X axis) weighted for study size (dot size) with 95% CI.

studies in which the inclusion times ranging from 1954 to 1997, comprising 21,523 patients. Our review includes articles published from 1991 onwards, with mid-time points of studies ranging from 1970 to 2003, and comprises a considerably higher number of patients (60,822), resulting in additional statistical power.

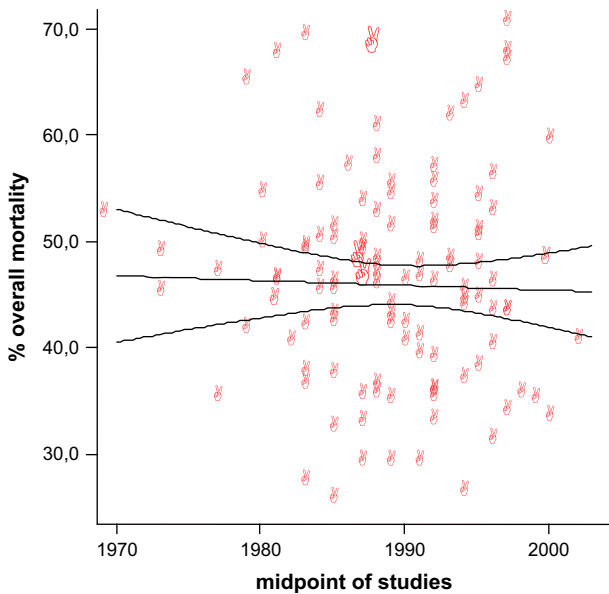


Fig. 3. Meta regression of 115 studies reporting on % overall mortality (Y axis) against midpoint of the study (X axis) weighted for study size (dot size) with 95% CI.

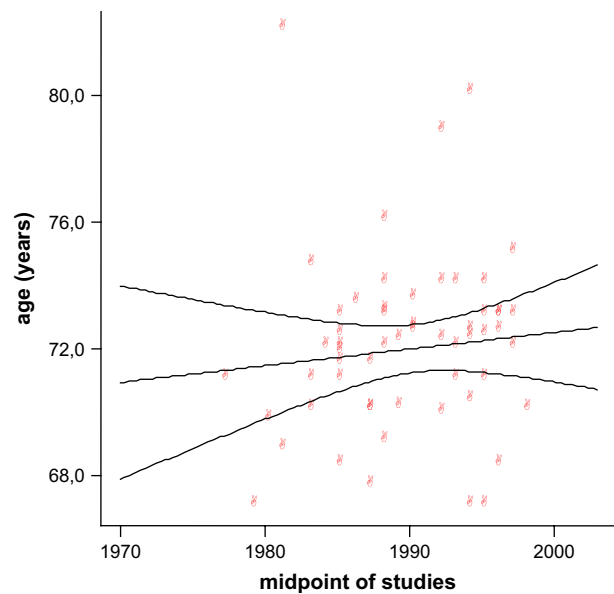


Fig. 5. Meta regression of 58 studies reporting on age of the patients (Y axis) against midpoint of the studies (X axis) with 95% CI.

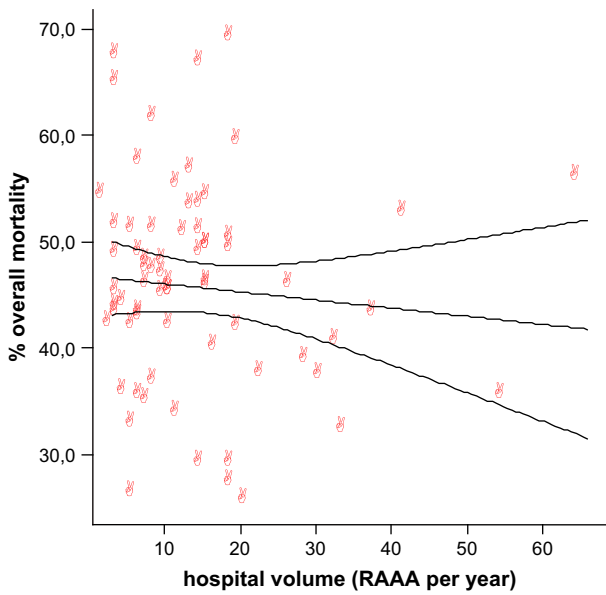


Fig. 6. Meta regression of 69 studies reporting on % overall mortality (Y axis) against hospital volume (X axis) with 95% CI.

We found an association between increasing age and mid-time point of the studies, which may explain why our findings are different from Bown *et al.* Aging of the population and a more liberal trend towards surgical interventions in the elderly might eliminate improvements in emergency care, diagnostic facilities, anaesthesiology and intensive care. Intra-operative

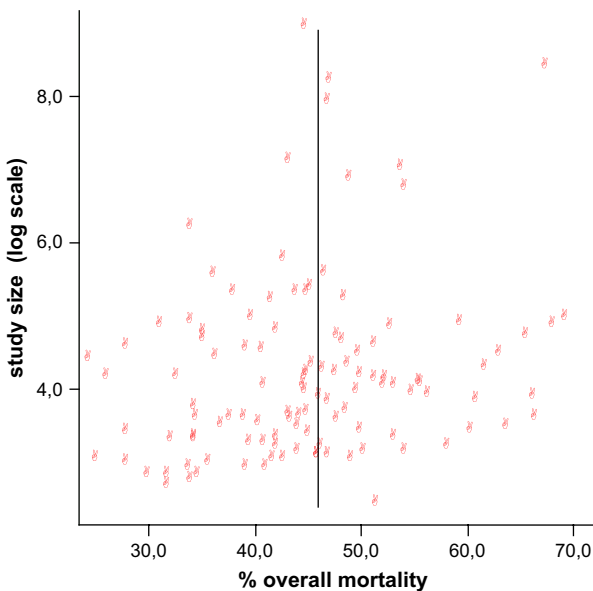


Fig. 7. Funnel plot to assess publication bias for articles reporting on overall mortality. The % overall mortality of each study on X axis against the size of the study on Y axis presented on log scale. Vertical axis presents mean overall mortality.

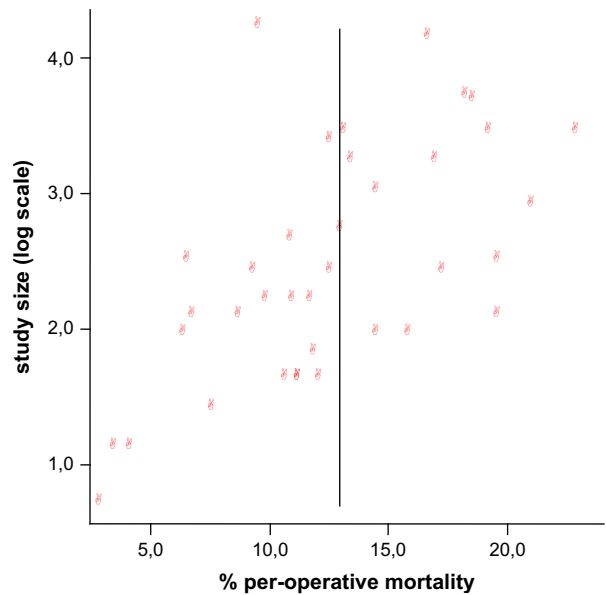


Fig. 8. Funnel plot to assess publication bias for articles reporting on per-operative mortality. The % per-operative mortality of each study on X axis against the size of the study on Y axis presented on log scale. Vertical axis presents mean per-operative mortality.

mortality showed a small increase from 6.3% in 1974 to 7.4% in 2003, which supports this idea.

Some limitations of our study should be mentioned. First, it is possible that besides the increasing age of the operated patients, complications of postoperative multi-organ failure are responsible for the persistence of high mortality rates in patients with RAAA. Important aspects of postoperative and operative care such as level of intensive care unit, experience of anaesthesiologists and intensivists could not be analysed in this study. Second, the publication bias found for studies reporting on intra-operative mortality limits conclusions from this outcome. Third, despite our efforts we may have missed eligible articles in our electronic or manual search. The literature search resulted in a large number of case series often containing small numbers of patients. We excluded series with fewer than forty patients, and as a result some data may have been lost from the meta-analysis. We included population based studies generated from national databases. In some of these reports clear confirmation of the ruptured nature of the aortic aneurysm is lacking. This may have confounded our analysis by the inadvertent inclusion of symptomatic abdominal aortic aneurysms. Furthermore, due to the absence of randomised controlled trials on this subject, only observational studies were retrieved which results in a number of biases. For example, retrospective studies often fail



to describe important factors such as time between diagnoses and treatment, haemodynamic status or patients' medical history. These factors influence mortality rates significantly, but were unavailable for analyses. There was a significant difference in outcomes between prospective and retrospective studies. However, the number of prospective studies was relatively low, which makes interpretation of these results difficult. We tried to reduce the large degree of clinical heterogeneity by defining strict inclusion and exclusion criteria.

We found a trend in favour of high-volume hospitals in terms of mortality, but it was not possible to establish a cut-off point for the number of RAAA repairs a hospital should perform to reduce mortality rates from these data. A recent meta-analysis<sup>26</sup> investigated the volume-outcome relationship for RAAA repair and showed a significant reduction in mortality rate in high-volume centers. They included 11 original studies of which 5 were published before 1991. Our search was restricted to articles published from 1991 onwards to evaluate recent data on mortality rates and this could explain the lack of a significant association in our meta-analysis. It has been postulated that patients with RAAA treated at trauma centers have decreased mortality compared with non designated hospitals of equal volume size because of the wide range of immediately available resources in trauma centers.<sup>27</sup> Readily available supplies of blood and coagulation products, rapid mobilisation of operating resources and experienced vascular surgeons also might play a role. Availability of a trained vascular surgeon and an intensive care unit staffed appropriately have been linked to better results of AAA repair.<sup>28–30</sup> We were unable to examine these in the present study.

Despite improvements in emergency care, diagnostic facilities, anaesthesiology and intensive care overall mortality of patients undergoing open repair for RAAA has not changed. Increased age of patients selected for operation may explain this finding.

#### *Acknowledgment*

The authors thank Ingrid Riphagen, VuMC medical library Amsterdam, for her assistance with the search strategy.

#### *Funding*

This study was supported by the Dutch heart foundation (2002B197).

## **Appendix**

### **Search strategy**

#### *Embase*

'Abdominal aorta aneurysm'/exp/dm\_su,dm\_th OR ('abdominal aorta aneurysm'/exp AND (mortality/de OR 'surgical mortality'/de)) OR ('aorta aneurysm'/de/dm\_su,dm\_th OR 'aorta rupture'/de/dm\_su,dm\_th OR 'aorta dissecting aneurysm'/de/dm\_su,dm\_th) AND (abdomen/de OR abdom\* OR thoracoabdom\*) OR ('aneurysm rupture'/de/dm\_su,dm\_th OR 'dissecting aneurysm'/de/dm\_su,dm\_th) AND (abdomen/de OR abdom\* OR thoracoabdom\*) AND (aorta/de OR 'abdominal aorta'/de OR aorta OR aortic) AND rupture\* OR emergen\* OR acute OR spontaneous\* AND Survival/exp OR Prognosis/de OR Prediction/de OR Forecasting/de OR 'Treatment outcome'/exp OR Mortality/de OR 'Surgical mortality'/de OR 'Clinical trial'/exp OR Comorbidity/de OR Morbidity/de OR 'Cohort analysis'/de OR 'Postoperative complication'/exp OR 'Postoperative period'/de OR Complication/de OR Evaluation/de OR 'Comparative study'/de OR survival:ti OR mortality:ti OR outcome\*:ti OR comorbidity:ti OR morbidity:ti OR fatality OR complicat\*.

NOT Review:it OR Note:it OR Letter:it OR Editorial:it OR 'case control study'/de OR 'Case report'/de OR 'Retrospective study'/de OR 'Practice guideline'/de OR 'Mass screening'/exp AND/limit English:la OR german:la OR french:la OR spanish:la OR dutch:la AND/limit from1991.

#### *Pubmed*

("Aortic Aneurysm, Abdominal/therapy"[MeSH] OR "Aortic Aneurysm, Abdominal/mortality"[MeSH] OR ("Aortic Aneurysm/therapy"[MeSH:noexp] OR "Aortic Aneurysm/mortality"[MeSH:noexp] OR "Aortic Rupture/therapy"[MeSH:noexp] OR "Aortic Rupture/mortality"[MeSH:noexp] OR ("Aneurysm, ruptured/therapy"[MeSH:noexp] OR "Aneurysm, ruptured/mortality"[MeSH:noexp]) AND (aorta[tw] OR aortic[tw])) AND ("Abdomen"[MeSH] OR abdom\*[ti] OR thoracoabdom\*[tw])) AND (rupture\*[tw] OR emergen\*[tw] OR acute[tw] OR spontaneous\*[tw]) AND ("Disease-Free Survival"[MeSH] OR Prognosis[-MeSH:NoExp] OR "Medical Futility"[MeSH] OR "Treatment Outcome"[MeSH] OR "Mortality"[MeSH] OR "mortality"[Subheading] OR clinical trial[pt] OR "Comorbidity"[MeSH] OR morbidity[mesh] OR "Survival"[MeSH] OR "Cohort Studies"[MeSH] OR survival[ti] OR mortality[ti] OR outcome\*[ti] OR

comorbidity[ti] OR morbidity[ti] OR fatality or "Post-operative Complications"[MeSH] OR postoperative period[mesh] OR complicat\*[tw] OR complications[sh] OR evaluation studies[pt] OR evaluation studies [mesh] OR comparative study[pt]) NOT (review[pt] OR case-control studies[mh] OR retrospective studies[mh] OR case reports[pt] OR practice guideline [publication type] OR comment [publication type] OR Editorial [Publication Type] OR Letter [Publication Type] OR mass screening [mesh]) AND (English[la] OR german[la] OR french[la] OR spanish[la] OR dutch[la]).

## References

- BENGTSSON H, BERGQVIST D. Ruptured abdominal aortic aneurysm: a population-based study. *J Vasc Surg* 1993;18(1):74–80.
- JOHANSSON G, SWEDENBORG J. Ruptured abdominal aortic aneurysms: a study of incidence and mortality. *Br J Surg* 1986;73(2):101–103.
- MEALY K, SALMAN A. The true incidence of ruptured abdominal aortic aneurysms. *Eur J Vasc Surg* 1988;2(6):405–408.
- KANTONEN I, LEPANTALO M, BROMMELS M, LUTHER M, SALENIUS JP, YLONEN K. Mortality in ruptured abdominal aortic aneurysms. The Finnvasc Study Group. *Eur J Vasc Endovasc Surg* 1999;17(3):208–212.
- SEMMENS JB, NORMAN PE, LAWRENCE-BROWN MM, HOLMAN CD. Influence of gender on outcome from ruptured abdominal aortic aneurysm. *Br J Surg* 2000;87(2):191–194.
- AKKERSDIJK GJM, VAN DER GY, VAN BOCKEL JH, DE VRIES AC, EIKELBOOM BC. Mortality rates associated with operative treatment of infrarenal abdominal aortic aneurysm in The Netherlands. *Br J Surg* 1994;81(5):706–709.
- DARDIK A, BURLEYSON GP, BOWMAN H, GORDON TA, WILLIAMS GM, WEBB TH *et al.* Surgical repair of ruptured abdominal aortic aneurysms in the state of Maryland: factors influencing outcome among 527 recent cases. *J Vasc Surg* 1998;28(3):413–420.
- KAZMERS A, PERKINS AJ, JACOBS LA. Outcomes after abdominal aortic aneurysm repair in those > or =80 years of age: recent Veterans Affairs experience. *Ann Vasc Surg* 1998;12(2):106–112.
- WEN SW, SIMUNOVIC M, WILLIAMS JI, JOHNSTON KW, NAYLOR CD. Hospital volume, calendar age, and short term outcomes in patients undergoing repair of abdominal aortic aneurysms: the Ontario experience, 1988–92. *J Epidemiol Community Health* 1996;50(2):207–213.
- VISSER P, AKKERSDIJK GJ, BLANKENSTEIJN JD. In-hospital operative mortality of ruptured abdominal aortic aneurysm: a population-based analysis of 5593 patients in The Netherlands over a 10-year period. *Eur J Vasc Endovasc Surg* 2005;30(4):359–364.
- HELLER JA, WEINBERG A, ARONS R, KRISHNASASTRY KV, LYON RT, DEITCH JS *et al.* Two decades of abdominal aortic aneurysm repair: have we made any progress? *J Vasc Surg* 2000;32(6):1091–1100.
- HALLIN A, BERGQVIST D, HOLMBERG L. Literature review of surgical management of abdominal aortic aneurysm. *Eur J Vasc Endovasc Surg* 2001;22(3):197–204.
- 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(6):714–730.
- BLANKENSTEIJN JD, LINDENBURG FP, VAN DER GY, EIKELBOOM BC. Influence of study design on reported mortality and morbidity rates after abdominal aortic aneurysm repair. *Br J Surg* 1998;85(12):1624–1630.
- HAUG ES, ROMUNDSTAD P, SAETHER OD, JORGENVAG R, MYHRE HO. Quality of data reported on abdominal aortic aneurysm repair—a comparison between a national vascular and a national administrative registry. *Eur J Vasc Endovasc Surg* 2005;29(6):571–578.
- JENSEN LP, NIELSEN OM, SCHROEDER TV. The importance of complete follow-up for results after femoro-infrapopliteal vascular surgery. *Eur J Vasc Endovasc Surg* 1996;12(3):282–286.
- KANTONEN I, LEPANTALO M, SALENIUS JP, MATZKE S, LUTHER M, YLONEN K. Mortality in abdominal aortic aneurysm surgery—the effect of hospital volume, patient mix and surgeon's case load. *Eur J Vasc Endovasc Surg* 1997;14(5):375–379.
- KATZ DJ, STANLEY JC, ZELENOCK GB. Operative mortality rates for intact and ruptured abdominal aortic aneurysms in Michigan: an eleven-year statewide experience. *J Vasc Surg* 1994;19(5):804–815.
- MANHEIM LM, SOHN MW, FEINGLASS J, UJIKI M, PARKER MA, PEARCE WH *et al.* Hospital vascular surgery volume and procedure mortality rates in California, 1982–1994. *J Vasc Surg* 1998;28(1):45–58.
- STROUP DF, BERLIN JA, MORTON SC, OLKIN I, WILLIAMSON GD, RENNIE D *et al.* Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA* 2000;283(15):2008–2012.
- LANDIS JR, KOCH GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33(1):159–174.
- BASNYAT PS, BIFFIN AH, MOSELEY LG, HEDGES AR, LEWIS MH. Mortality from ruptured abdominal aortic aneurysm in Wales. *Br J Surg* 1999;86(6):765–770.
- CHOKSY SA, QUICK CR, WILMINK ABM. Ruptured abdominal aortic aneurysm in the Huntingdon district: a 10-year experience. *Ann R Coll Surg Engl* 1999;81(1):27–31.
- DROTT C, ARFVIDSSON B, ORTENWALL P, LUNDHOLM K. Age-standardized incidence of ruptured aortic aneurysm in a defined Swedish population between 1952 and 1988: mortality rate and operative results. *Br J Surg* 1992;79(2):175–179.
- GLOVICZKI P, PAIROLERO PC, MUCHA J, FARNELL MB, HALLETT J, ILSTRUP DM *et al.* Ruptured abdominal aortic aneurysms: repair should not be denied. *J Vasc Surg* 1992;15(5):851–859.
- HOLT PJ, POLONIECKI JD, GERRARD D, LOFTUS IM, THOMPSON MM. Meta-analysis and systematic review of the relationship between volume and outcome in abdominal aortic aneurysm surgery. *Br J Surg* 2007;94(4):395–403.
- UTTER GH, MAIER RV, RIVARA FP, NATHENS AB. Outcomes after ruptured abdominal aortic aneurysms: the "halo effect" of trauma center designation. *J Am Coll Surg* 2006;203(4):498–505.
- BIRKMEYER JD, STUKEL TA, SIEWERS AE, GOODNEY PP, WENNBERG DE, LUCAS FL. Surgeon volume and operative mortality in the United States. *N Engl J Med* 2003;349(22):2117–2127.
- PRONOVOST PJ, ANGUS DC, DORMAN T, ROBINSON KA, DREMSIZOV TT, YOUNG TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA* 2002;288(17):2151–2162.
- DUECK AD, KUCEY DS, JOHNSTON KW, ALTER D. Survival after ruptured abdominal aortic aneurysm: effect of patient, surgeon, and hospital factors. *J Vasc Surg* 2004;39(6):1253–1260.
- CHEN JC, HILDEBRAND HD, SALVIAN AJ, HSIANG YN, TAYLOR DC. Progress in abdominal aortic aneurysm surgery: four decades of experience at a teaching center. *Cardiovasc Surg* 1997;5(2):150–156.
- THEVENET A, FRANCOIS F, ALBAT B. Progress in the surgery of abdominal aortic aneurysm. *Chirurgie* 1991;117(2):173–179.
- GHLIARDI G, SCORZA R, BORTOLANI E, DE MONTI M, LONGHI F, RUBERTI U. Rupture of abdominal aortic aneurysms into the major abdominal veins. *J Cardiovasc Surg (Torino)* 1993;34(1):39–47.
- TROTTER MC, ILABACA PA. Ruptured abdominal aortic aneurysms: a retrospective look at a ten-year interval. *Vasc Surg* 1993;27(3):183–186.
- POULIAS GE, DOUNDOULAKIS N, SKOUTAS B, HADDAD H, KARKANIAS G, LYBERIADES D. Abdominal aneurysmectomy and determinants of improved results and late survival. Surgical considerations in 672 operations and 1–15 year follow-up. *J Cardiovasc Surg (Torino)* 1994;35(2):115–121.

- 36 JAAKKOLA P, HIPPELAINEN M, OKSALA I. Infrarenal aortofemoral bypass surgery: risk factors and mortality in 330 patients with abdominal aortic aneurysm or aortoiliac occlusive disease. *Ann Chir Gynaecol* 1996;**85**(1):28–35.
- 37 BONAMIGO TP, SILVA JH, SILIPRANDI LR. Ruptured abdominal aortic aneurysm. Analysis of 50 procedures. *Int Angiol* 1991;**10**(3):133–140.
- 38 SOISALON-SOININEN S, SALO JA, PERHONIEMI V, MATTILA S. Emergency surgery of non-ruptured abdominal aortic aneurysm. *Ann Chir Gynaecol* 1999;**88**(1):38–43.
- 39 COHEN JR, BIRNBAUM E, KASSAN M, WISE L. Experience in managing 70 patients with ruptured abdominal aortic aneurysms. *N Y State J Med* 1991;**91**(3):97–100.
- 40 CHENG SWK, WONG J. Abdominal aortic aneurysms in Hong Kong. *Asian J Surg* 1994;**17**(4):377–383.
- 41 ALBES JM, ALEXANDER K, LAAS J. Ruptured abdominal aortic aneurysms: risk factors of early mortality. *Vasa J Vasc Dis* 1991;**20**(4):374–381.
- 42 REITSMA JB, PLEUMEEKERS HJCM, HOES AW, KLEIJNEN J, DE GROOT RM, JACOBS MJHM *et al.* Increasing incidence of aneurysms of the abdominal aorta in The Netherlands. *Eur J Vasc Endovasc Surg* 1996;**12**(4):446–451.
- 43 PRAGER M, TEUFELSBAUER H, NANOBASHVILI J, KRETSCHMER G, TRUBEL W, HUK I *et al.* Abdominal vascular surgery emergencies: abdominal aortic aneurysm, acute mesenteric ischemia—indications, technique, results. *Acta Med Austriaca* 2000;**27**(5):145–151.
- 44 CHAKFE N, LOOS G, NICOLINI P, BILLAUD P, BEAUFIGEAU M, KRETZ JG *et al.* Surgery of aortic aneurysms in patients older than 70: survival expectancy and quality of life. *J Mal Vasc* 1995;**20**(4):313–316.
- 45 STONEBRIDGE PA, CALLAM MJ, BRADBURY AW, MURIE JA, JENKINS AM, RUCKLEY CV. Comparison of long-term survival after successful repair of ruptured and non-ruptured abdominal aortic aneurysm. *Br J Surg* 1993;**80**(5):585–586.
- 46 MCCREADY RA, SIDERY S, PITTMAN JN, HEROD GT, HALBROOK HG, FEHRENBACHER JW *et al.* Ruptured abdominal aortic aneurysms in a private hospital: a decade's experience (1980–1989). *Ann Vasc Surg* 1993;**7**(3):225–228.
- 47 RUBERTI U, ARPESANI A, GIORGETTI PL, BORTOLANI EM, GHILARDI G, RAMPOLDI V *et al.* Surgical treatment of abdominal aortic aneurysm. A ten-year experience (1980–1989) referred to 1725 patients operated on. *Panminerva Med* 1991;**33**(3):131–139.
- 48 JOHANSEN K, KOHLER TR, NICHOLLS SC, ZIERLER RE, CLOWES AW, KAZMERS A. Ruptured abdominal aortic aneurysm: the Harborview experience. *J Vasc Surg* 1991;**13**(2):240–245.
- 49 GIORGETTI PL, ARPESANI A, BORTOLANI EM, RAMPOLDI V, RIGNANO A, GHILARDI G *et al.* Abdominal aortic aneurysms surgery in over 75 years old patients. Experience in 142 cases treated between 1980–1989. *Panminerva Med* 1991;**33**(1):19–25.
- 50 OLSEN PS, SCHROEDER T, AGERSKOV K, RODER O, SORENSEN S, PERKO M *et al.* Surgery for abdominal aortic aneurysms. A survey of 656 patients. *J Cardiovasc Surg (Torino)* 1991;**32**(5):636–642.
- 51 HANS SS. Concurrent audit of early outcome for 1617 consecutive arterial reconstructions. *Surg Gynecol Obstet* 1993;**176**(4):382–386.
- 52 SCOTT A, BAILLIE CT, SUTTON GL, SMITH A, BOWYER RC. Audit of 200 consecutive aortic aneurysm repairs carried out by a single surgeon in a district hospital: results of surgery and factors affecting outcome. *Ann R Coll Surg Engl* 1992;**74**(3):205–210.
- 53 ABURAHMA AF, WOODRUFF BA, LUCENTE FC, STUART SP, BOLAND JP. Factors affecting survival of patients with ruptured abdominal aortic aneurysm in a West Virginia community. *Surg Gynecol Obstet* 1991;**172**(5):377–382.
- 54 SAMY AK, WHYTE B, MACBAIN G. Abdominal aortic aneurysm in Scotland. *Br J Surg* 1994;**81**(8):1104–1106.
- 55 BRADBURY AW, ADAM DJ, MAKHDOOMI KR, STUART WP, MURIE JA, JENKINS AM *et al.* A 21-year experience of abdominal aortic aneurysm operations in Edinburgh. *Br J Surg* 1998;**85**(5):645–647.
- 56 FAROOQ MM, FREISCHLAG JA, SEABROOK GR, MOON MR, APRAHAMIAN C, TOWNE JB. Effect of the duration of symptoms, transport time, and length of emergency room stay on morbidity and mortality in patients with ruptured abdominal aortic aneurysms. *Surgery* 1996;**119**(1):9–14.
- 57 PANNETON JM, LASSONDE J, LAURENDEAU F. Ruptured abdominal aortic aneurysm: impact of comorbidity and postoperative complications on outcome. *Ann Vasc Surg* 1995;**9**(6):535–541.
- 58 RAMO OJ, GRONLUND S, TOIVIO I, MOKKA RE. Can we achieve better results by operating on smaller abdominal aortic aneurysms? *Vasa* 1995;**24**(3):270–274.
- 59 MIANI S, GIORGETTI PL, ARPESANI A, GIUFFRIDA GF, BIASI GM, RUBERTI U. Spontaneous aorto-caval fistulas from ruptured abdominal aortic aneurysms. *Eur J Vasc Surg* 1994;**8**(1):36–40.
- 60 GOSSELIN C, LABBE R, DOUVILLE Y, NOEL HP. Ruptured abdominal aortic aneurysm: long-term survival. *Ann Chir* 1991;**45**(9):774–777.
- 61 VAN DONGEN HPA, LEUSINK JA, MOLL FL, BRONS FM, DE BOER A. Ruptured abdominal aortic aneurysms: factors influencing postoperative mortality and long-term survival. *Eur J Vasc Endovasc Surg* 1998;**15**(1):62–66.
- 62 ROSENTHAL D, MCKINSEY JF, ERDOES LS, HUNGERPILLAR JC, CLARK MD, LAMIS PA *et al.* Ruptured abdominal aortic aneurysm: factors affecting survival and long-term results. *Vasc Surg* 1992;**26**(1):53–58.
- 63 JOHNSTON KW, AMELI FM, AU HH, BAIRD RJ, BALACHANDRA VK, BARBER GG *et al.* Ruptured abdominal aortic aneurysm: six-year follow-up results of a multicenter prospective study. *J Vasc Surg* 1994;**19**(5):888–900.
- 64 KATZ SG, KOHL RD, RICHARDSON JD. Ruptured abdominal aortic aneurysms: a community experience. *Arch Surg* 1994;**129**(3):285–290.
- 65 CORMIER F, VEROUX P, FICHELE JM, MARZELLE J, CORMIER JM. Surgery of aneurysm of the subrenal abdominal aorta in patients over 80 years of age. *Presse Med* 1993;**22**(37):1861–1864.
- 66 IMIG H, SCHRODER A, RIEPE G. The infrarenal aortic aneurysm – indications for surgery and late results. *Zentralbl Chir* 1996;**121**(3):223–227.
- 67 HENDERSON A, EFFENEY D. Morbidity and mortality after abdominal aortic surgery in a population of patients with high cardiovascular risk. *Aust N Z J Surg* 1995;**65**(6):417–420.
- 68 SLOOTMANS FC, VAN DER VLIET JA, REINAERTS HH, VAN ROYE SF, BUSKENS FG. Relaparotomies after ruptured abdominal aortic aneurysm repair. *Eur J Vasc Surg* 1994;**8**(3):342–345.
- 69 MAGEE TR, SCOTT DJ, DUNKLEY A, ST JOHNSTON J, CAMPBELL WB, BAIRD RN *et al.* Quality of life following surgery for abdominal aortic aneurysm. *Br J Surg* 1992;**79**(10):1014–1016.
- 70 MEESTERS RCT, VAN DER GRAAF Y, VOS A, EIKELBOOM BC. Ruptured aortic aneurysm: early postoperative prediction of mortality using an organ system failure score. *Br J Surg* 1994;**81**(4):512–516.
- 71 BOCCARA G, PERRIGAULT PF, COLSON P, MARTY-ANE C, CUCHET D, PECASTAING M *et al.* Predictive factors of mortality and morbidity of ruptured infrarenal aortic aneurysm surgery. *J Cardiothorac Vasc Anesth* 1994;**8**(3 Suppl. 2):187.
- 72 MARTINEZ R, GARCES D, PODEUR L, ABDEL AK, LAFFON M, CASTELLANI L. Ruptured abdominal aortic aneurysm. A ten year experience. *J Cardiovasc Surg (Torino)* 1997;**38**(1):1–6.
- 73 SAITA J, LAARA E, REINILA A, IMMONEN K, JUVONEN T. The rupture type determines the outcome for ruptured abdominal aortic aneurysm patients. *Ann Chir Gynaecol* 1997;**86**(1):24–29.
- 74 KOSKAS F, KIEFFER E. Surgery for ruptured abdominal aortic aneurysm: early and late results of a prospective study by the AURC in 1989. *Ann Vasc Surg* 1997;**11**(1):90–99.
- 75 CALLAM MJ, HAIART D, MURIE JA, RUCKLEY CV, JENKINS M. Ruptured aortic aneurysm: a proposed classification. *Br J Surg* 1991;**78**(9):1126–1129.
- 76 BOHMER RD, FLEISCHL J, KNIGHT D. Quality of life after emergency abdominal aortic aneurysm repair. *Aust N Z J Surg* 1999;**69**(6):447–449.
- 77 VAN DER VLIET JA, KOUWENBERG PPGM, MUYTJENS HL, BARENDREGT WB, BOLL APM, BUSKENS FGM. Relevance of

- bacterial cultures of abdominal aortic aneurysm contents. *Surgery* 1996;**119**(2):129–132.
- 78 SEIWERT AJ, ELMORE JR, YOUKEY JR, FRANKLIN DP. Ruptured abdominal aortic aneurysm repair: the financial analysis. *Am J Surg* 1995;**170**(2):91–96.
  - 79 SZOSTEK M, MALEK AK, CIERPKA L, GLOWINSKI S, MACKIEWICZ Z, MICHALAK J *et al.* Surgical management of abdominal aortic aneurysms in Poland. A multi-centre study. *Int Angiol* 1993;**12**(4):318–322.
  - 80 LAWRENCE PF, GAZAK C, BHIRANGI L, JONES B, BHIRANGI K, ODERICH G *et al.* The epidemiology of surgically repaired aneurysms in the United States. *J Vasc Surg* 1999;**30**(4):632–640.
  - 81 SEMMENS JB, NORMAN PE, LAWRENCE-BROWN MM, BASS AJ, HOLMAN CD. Population-based record linkage study of the incidence of abdominal aortic aneurysm in Western Australia in 1985–1994. *Br J Surg* 1998;**85**(5):648–652.
  - 82 ELIASON JL, WAINESS RM, DIMICK JB, COWAN J, HENKE PK, STANLEY JC *et al.* The effect of secondary operations on mortality following abdominal aortic aneurysm repair in the United States: 1988–2001. *Vasc Endovascular Surg* 2005;**39**(6):465–472.
  - 83 JARVINEN O, LAURIKKA J, SISTO T, TARKKA MR. Intestinal ischemia following surgery for aorto-iliac disease. A review of 502 consecutive aortic reconstructions. *Vasa* 1996;**25**(2):148–155.
  - 84 RODDY SP, DARLING III RC, MAHARAJ D, OZSVATH KJ, MEHTA M, PATY PSK *et al.* Should ruptured abdominal aortic aneurysms be repaired in the octogenarian? *Cardiovasc Surg* 2003;**11**(5):337–340.
  - 85 BRADBURY AW, BACHOO P, MILNE AA, DUNCAN JL. Platelet count and the outcome of operation for ruptured abdominal aortic aneurysm. *J Vasc Surg* 1995;**21**(3):484–491.
  - 86 BJORCK M, BERGQVIST D, TROENG T. Incidence and clinical presentation of bowel ischaemia after aortoiliac surgery—2930 operations from a population-based registry in Sweden. *Eur J Vasc Endovasc Surg* 1996;**12**(2):139–144.
  - 87 RUTLEDGE R, OLLER DW, MEYER AA, JOHNSON Jr GJ. A statewide, population-based time-series analysis of the outcome of ruptured abdominal aortic aneurysm. *Ann Surg* 1996;**223**(5):492–502.
  - 88 TEUFELSBAUER H, PRUSA AM, WOLFF K, SAHAL M, HOLZENBEIN T, KRETSCHMER G *et al.* Ruptured abdominal aortic aneurysms: status quo after a quarter century of treatment experience. *Wien Klin Wochenschr* 2003;**115**(15–16):584–589.
  - 89 AKKERSDIJK GJM, VAN BOCKEL JH. Ruptured abdominal aortic aneurysm: initial misdiagnosis and the effect on treatment. *Eur J Surg* 1998;**164**(1):29–34.
  - 90 THORBAN S, PFLUGBEIL G, GRUNDEI T, DORRLER J, BRANDL R. Twenty years of surgery for abdominal aortic aneurysms: multivariate analysis of perioperative risk factors in 528 patients. *Gefasschirurgie* 2003;**8**(Suppl. 1):S53–S58.
  - 91 EVANS SM, ADAM DJ, MURIE JA, JENKINS AM, RUCKLEY CV, BRADBURY AW. Training in abdominal aortic aneurysm (AAA) repair: 1987–1997. *Eur J Vasc Endovasc Surg* 1999;**18**(5):430–433.
  - 92 ADAM DJ, MOHAN IV, STUART WP, BAIN M, BRADBURY AW. Community and hospital outcome from ruptured abdominal aortic aneurysm within the catchment area of a regional vascular surgical service. *J Vasc Surg* 1999;**30**(5):922–928.
  - 93 PFEIFFER T, REIHER L, GRABITZ K, SANDMANN W. Results of conventional surgical therapy of abdominal aortic aneurysms since the beginning of the “endovascular era”. *Chirurgia* 2000;**71**(1):72–79.
  - 94 LAZARIDES MK, ARVANITIS DP, DRISTA H, STARAMOS DN, DAYANTAS JN. POSSUM and APACHE II scores do not predict the outcome of ruptured infrarenal aortic aneurysms. *Ann Vasc Surg* 1997;**11**(2):155–158.
  - 95 VAMMEN S, LINDHOLT J, HENNEBERG EW, FASTING H. A comparative study of iliac and abdominal aortic aneurysms. *Int Angiol* 2000;**19**(2):152–157.
  - 96 TURTON EPL, SCOTT DJA, DELBRIDGE M, SNOWDEN S, KESTER RC. Ruptured abdominal aortic aneurysm: a novel method of outcome prediction using neural network technology. *Eur J Vasc Endovasc Surg* 2000;**19**(2):184–189.
  - 97 LEVISON JA, HALPERN VJ, KLINE RG, FAUST GR, COHEN JR, FREISCHLAG JA *et al.* Perioperative predictors of colonic ischemia after ruptured abdominal aortic aneurysm. *J Vasc Surg* 1999;**29**(1):40–47.
  - 98 SANDISON AJP, WYNCOLL DLA, EDMONDSON RC, VAN HEERDEN N, BEALE RJ, TAYLOR PR. ICU protocol may affect the outcome of non-elective abdominal aortic aneurysm repair. *Eur J Vasc Endovasc Surg* 1998;**16**(4):356–361.
  - 99 SEBESTA P, KLIKA T, ZDRAHAL P, KRAMAR J. Ruptured abdominal aortic aneurysm: role of initial delay on survival. *J Mal Vasc* 1998;**23**(5):361–367.
  - 100 HEIKKINEN M, SALENIUS JP, AUVINEN O. Ruptured abdominal aortic aneurysm in a well-defined geographic area. *J Vasc Surg* 2002;**36**(2):291–296.
  - 101 KAZMERS A, PERKINS AJ, JACOBS LA. Aneurysm rupture is independently associated with increased late mortality in those surviving abdominal aortic aneurysm repair. *J Surg Res* 2001;**95**(1):50–53.
  - 102 JANCZYK RJ, HOWELLS GA, BAIR HA, HUANG R, BENDICK PJ, ZELENACK GB. Hypothermia is an independent predictor of mortality in ruptured abdominal aortic aneurysms. *Vasc Endovascular Surg* 2004;**38**(1):37–42.
  - 103 PODLAHA J, GREGOR Z, ROUBAL P, HORKY B, DVORAK M. Ruptured abdominal aortic aneurysm—outcomes in the last ten years. *Bratisl Lek Listy* 2000;**101**(4):191–193.
  - 104 ARTIGUES I, RIMBAU E, LOZANO P, PLAZA A, DIAZ M, COROMINAS C *et al.* Long-term survival in patients with abdominal aortic aneurysm. *Angiologia* 2000;**52**(1):13–18.
  - 105 ALRIC P, RYCKWAERT F, PICOT MC, BRANCHEREAU P, COLSON P, MARY H *et al.* Ruptured aneurysm of the infrarenal abdominal aorta: impact of age and postoperative complications on mortality. *Ann Vasc Surg* 2003;**17**(3):277–283.
  - 106 BURGER T, MEYER F, TAUTENHAHN J, HALLOUL Z. Ruptured infrarenal aortic aneurysm—a critical evaluation. *Vasa* 1999;**28**(1):30–33.
  - 107 FICHTNER-FEIGL S, LARENA-AVELLANEDA A, DEBUS ES. Survival, complications, and risk factors of ruptured aortic aneurysms. A retrospective analysis. *Gefasschirurgie* 2003;**8**(3):200–205.
  - 108 ALONSO-PEREZ M, SEGURA RJ, PITA S, CAL L. Surgical treatment of ruptured abdominal aortic aneurysms in the elderly. *Ann Vasc Surg* 1999;**13**(6):592–598.
  - 109 STONE PA, HAYES JD, ABURAHMA AF, JACKSON JM, SANTOS AN, FLAHERTY SK. Ruptured abdominal aortic aneurysms: 15 years of continued experience in a southern West Virginia community. *Ann Vasc Surg* 2005;**19**(6):851–857.
  - 110 MARKOVIC M, DAVIDOVIC L, MAKSIMOVIC Z, KOSTIC D, CINARA I, CVETKOVIC S *et al.* Ruptured abdominal aortic aneurysm. Predictors of survival in 229 consecutive surgical patients. *Herz* 2004;**29**(1):123–129.
  - 111 KESSLER U, BERGERT H, OCKERT D, SAEGER HD. Results and complications of ruptured abdominal aortic aneurysm repair. *Zentralbl Chir* 2002;**127**(8):664–668.
  - 112 ALONSO-PEREZ M, SEGURA RJ, SANCHEZ J, SICARD G, BARREIRO A, GARCIA M *et al.* Factors increasing the mortality rate for patients with ruptured abdominal aortic aneurysms. *Ann Vasc Surg* 2001;**15**(6):601–607.
  - 113 ROBINSON J, NAWAZ S, BEARD JD. Randomized, multicentre, double-blind, placebo-controlled trial of the use of aprotinin in the repair of ruptured abdominal aortic aneurysm. On behalf of the Joint Vascular Research Group. *Br J Surg* 2000;**87**(6):754–757.
  - 114 ADAM DJ, MILNE AA, EVANS SM, ROULSTON JE, LEE AJ, RUCKLEY CV *et al.* Serum amylase isoenzymes in patients undergoing operation for ruptured and non-ruptured abdominal aortic aneurysm. *J Vasc Surg* 1999;**30**(2):229–235.
  - 115 MAY J, WHITE GH, STEPHEN MS, HARRIS JP. Rupture of abdominal aortic aneurysm: concurrent comparison of outcome of those occurring after endovascular repair versus those occurring without previous treatment in an 11-year single-center experience. *J Vasc Surg* 2004;**40**(5):860–866.
  - 116 POSACIOGLU H, APAYDIN AZ, ISLAMOGLU F, CALKAVUR T, YAGDI T, ATAY Y *et al.* Adverse effects of cell saver in patients undergoing

- ruptured abdominal aortic aneurysm repair. *Ann Vasc Surg* 2002;**16**(4):450–455.
- 117 AXELROD DA, HENKE PK, WAKEFIELD TW, STANLEY JC, JACOBS LA, GRAHAM LM *et al.* Impact of chronic obstructive pulmonary disease on elective and emergency abdominal aortic aneurysm repair. *J Vasc Surg* 2001;**33**(1):72–76.
  - 118 PAI M, HANDA A, HANDS L, COLLIN J. Adequate vascular training opportunities can be provided without compromising patient care. *Eur J Vasc Endovasc Surg* 2002;**23**(6):524–527.
  - 119 HARRIS JR, FORBES TL, STEINER SH, LAWLOR DK, DEROSE G, HARRIS KA. Risk-adjusted analysis of early mortality after ruptured abdominal aortic aneurysm repair. *J Vasc Surg* 2005;**42**(3):387–391.
  - 120 CHENG SWK, TING ACW, TSANG SHY. Epidemiology and outcome of aortic aneurysms in Hong Kong. *World J Surg* 2003;**27**(2):241–245.
  - 121 TAMBYRAJA AL, STUART WP, SALA TA, MURIE JA, CHALMERS RT. Non-operative management of high-risk patients with abdominal aortic aneurysm. *Eur J Vasc Endovasc Surg* 2003;**26**(4):401–404.
  - 122 VOGEL TR, NACKMAN GB, BREVETTI LS, CROWLEY JG, BUENO MM, BANAVAGE A *et al.* Resource utilization and outcomes: effect of transfer on patients with ruptured abdominal aortic aneurysms. *Ann Vasc Surg* 2005;**19**(2):149–153.
  - 123 TRESKA V, NOVAK M. Rupture of abdominal aortic aneurysm—factors of mortality. *Bratisl Lek Listy* 2006;**107**(1–2):22–25.
  - 124 HO P, CHENG SWK, TING ACW, POON JTC. Improvement of mortality of ruptured abdominal aortic aneurysm patients over 12 years and its relationship with tracheostomy. *Ann Vasc Surg* 2006;**20**(2):175–182.
  - 125 WOZNIAK W, CIOSTEK P, NOSZCZYK W. Prospective analysis of early surgical treatment results in case of patients with ruptured abdominal aortic aneurysms. *Pol Przegl Chir* 2006;**78**(2):163–178.
  - 126 HECHELHAMMER L, LACHAT ML, WILDERMUTH S, BETTEX D, MAYER D, PFAMMATTER T. Midterm outcome of endovascular repair of ruptured abdominal aortic aneurysms. *J Vasc Surg* 2005;**41**(5):752–757.
  - 127 BOYLE JR, GIBBS PJ, KING D, SHEARMAN CP, RAPTIS S, PHILLIPS MJ. Predicting outcome in ruptured abdominal aortic aneurysm: a prospective study of 100 consecutive cases. *Eur J Vasc Endovasc Surg* 2003;**26**(6):607–611.
  - 128 ARYA N, MAKAR RR, LAU LL, LOAN W, LEE B, HANNON RJ *et al.* An intention-to-treat by endovascular repair policy may reduce overall mortality in ruptured abdominal aortic aneurysm. *J Vasc Surg* 2006;**44**(3):467–471.
  - 129 GRECO G, EGOROVA N, ANDERSON PL, GELIJNS A, MOSKOWITZ A, NOWYGRAD R *et al.* Outcomes of endovascular treatment of ruptured abdominal aortic aneurysms. *J Vasc Surg* 2006;**43**(3):453–459.
  - 130 TAMBYRAJA AL, DAWSON ARW, MURIE JA, CHALMERS RTA. Cardiac troponin I predicts outcome after ruptured abdominal aortic aneurysm repair. *Br J Surg* 2005;**92**(7):824–827.
  - 131 DAVIES MJ, MURPHY WG, MURIE JA, ELTON RA, BELL K, GILLON JG *et al.* Preoperative coagulopathy in ruptured abdominal aortic aneurysm predicts poor outcome. *Br J Surg* 1993;**80**(8):974–976.
  - 132 NICHOLLS SC, GARDNER JB, MEISSNER MH, JOHANSEN KH. Rupture in small abdominal aortic aneurysms. *J Vasc Surg* 1998;**28**(5):884–888.
  - 133 MAZIAK DE, LINDSAY TF, MARSHALL JC, WALKER PM. The impact of multiple organ dysfunction on mortality following ruptured abdominal aortic aneurysm repair. *Ann Vasc Surg* 1998;**12**(2):93–100.
  - 134 PIOTROWSKI JJ, RIPEPI AJ, YUHAS JP, ALEXANDER JJ, BRANDT CP, GLOVER JL *et al.* Colonic ischemia: the achilles heel of ruptured aortic aneurysm repair. *Am Surg* 1996;**62**(7):557–561.
  - 135 GORDON AC, PRYN S, COLLIN J, GRAY DWR, HANDS L, GARRARD C. Outcome in patients who require renal support after surgery for ruptured abdominal aortic aneurysm. *Br J Surg* 1994;**81**(6):836–838.
  - 136 BROWNING NG, LONG MA, BARRY R, NEL CJ, SCHALL R, MONK E. Ruptured abdominal aortic aneurysms—prognostic indicators and complications affecting mortality. A local experience. *S Afr J Surg* 1995;**33**(1):21–25.

Accepted 24 November 2007

Available online 15 January 2008