




BMJ Open Incidence and outcomes of acute mesenteric ischaemia: a systematic review and meta-analysis

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ABSTRACT

Objective To estimate the incidence of acute mesenteric ischaemia (AMI), proportions of its different forms and short-term and long-term mortality.

Design Systematic review and meta-analysis.

Data sources MEDLINE (Ovid), Web of Science, Scopus and Cochrane Library were searched until 26 July 2022.

Eligibility criteria Studies reporting data on the incidence and outcomes of AMI in adult populations.

Data extraction and synthesis Data extraction and quality assessment with modified Newcastle-Ottawa scale were performed using predeveloped standard forms. The outcomes were the incidence of AMI and its different forms in the general population and in patients admitted to hospital, and the mortality of AMI in its different forms.

Results From 3064 records, 335 full texts were reviewed and 163 included in the quantitative analysis. The mean incidence of AMI was 6.2 (95% CI 1.9 to 12.9) per 100 000 person years. On average 5.0 (95% CI 3.3 to 7.1) of 10 000 hospital admissions were due to AMI. Occlusive arterial AMI was the most common form constituting 68.6% (95% CI 63.7 to 73.2) of all AMI cases, with similar proportions of embolism and thrombosis. Overall short-term mortality (in-hospital or within 30 days) of AMI was 59.6% (95% CI 55.5 to 63.6), being 68.7% (95% CI 60.8 to 74.9) in patients treated before the year 2000 and 55.0% (95% CI 45.5 to 64.1) in patients treated from 2000 onwards ($p<0.05$). The mid/long-term mortality of AMI was 68.2% (95% CI 60.7 to 74.9). Mortality due to mesenteric venous thrombosis was 24.6% (95% CI 17.0 to 32.9) and of non-occlusive mesenteric ischaemia 58.4% (95% CI 48.6 to 67.7). The short-term mortality of revascularised occlusive arterial AMI was 33.9% (95% CI 30.7 to 37.4).

Conclusions In adult patients, AMI is a rarely diagnosed condition with high mortality, although with improvement of treatment results over the last decades. Two thirds of AMI cases are of occlusive arterial origin with potential for better survival if revascularised.

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INTRODUCTION

Acute mesenteric ischaemia (AMI) is a potentially fatal vascular catastrophe.¹ Inadequate blood flow to the intestine may result from mesenteric arterial embolism or thrombosis

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This systematic review used a comprehensive search for articles on the incidence and outcomes of acute mesenteric ischaemia.
- ⇒ A considerable number of studies was identified and included for mortality outcome.
- ⇒ Included studies were mainly retrospective single-centre studies including patients recruited over a long time period.
- ⇒ Meta-analyses on mortality according to age group or gender, and assessment of other outcomes were not possible.

or by acute mesenteric venous thrombosis (MVT).² Insufficient perfusion may also occur without an acute thrombo-embolic high-grade stenosis or occlusion of large mesenteric arteries—non-occlusive mesenteric ischaemia (NOMI).² AMI is said to be a rare condition, yet the incidence is poorly documented. Few studies have addressed it among the general population or hospitalised patients, and recent guidelines have, therefore, relied on estimated levels.² No systematic analysis on incidence of AMI is available. The most accurate report on the proportion of different forms of AMI comes from a population with an 87% autopsy rate studied between 1970 and 1982.³

In contrast to the lack of data on incidence, the poor outcome of AMI has been well demonstrated. The systematic analysis of 45 studies published before 2002 demonstrates an overall mortality of 74% or 64% depending on whether only supportive or unlimited care was applied.⁴ A review of 54 studies from 1956 to 2012 found in-hospital mortality of approximately 60% in the studies published from 2002 to 2012, and suggested a slight reduction in mortality over time.⁵ Data from the past decade suggest that some improvement may have taken place as a result of a multidisciplinary approach and

developments in many medical fields (eg, better diagnostics, endovascular procedures, management of short bowel syndrome, home parenteral nutrition).^{6–8} Whether this has truly resulted in improved outcomes from AMI is unknown.

The aim of this study was to clarify the incidence of AMI and its different forms among adults in the general population, and in those admitted to hospital and presenting to hospital emergency departments, and to determine the outcomes of AMI and its different forms stratified as to whether treatment was before or after the year 2000.

MATERIALS AND METHODS

A study protocol, following the items presented in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines⁹ was developed. Details of the protocol were registered on PROSPERO and can be accessed at https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=247148.

Inclusion criteria for studies

Studies meeting the following criteria were included in the review:

1. Conducted in:
 - General adult (≥ 18 years old) population (whole country, sub-national area, administrative area, area served by hospital) in any of the 218 countries of the world,¹⁰
 - Adult patients admitted to hospital and/or
 - Adult patients presenting to hospital emergency departments.
2. Presenting data on:
 - AMI incidence or containing data for the numerator and denominator of the estimation fraction, with the diagnosis of AMI based on clinical data, imaging, laparotomy and/or autopsy report. The incidence of AMI in this review was defined as the number of patients newly diagnosed with AMI in the population of interest over 12 months. The incidence of the subtypes of AMI—occlusive AMI (occlusive arterial AMI), NOMI, and MVT, was also explored and/or
 - AMI outcomes: all-cause mortality (in-hospital, 30-day and the longest reported); intensive care unit length of stay, hospital length of stay and need for home parenteral nutrition.

Literature search

Biomedical literature databases MEDLINE (Ovid), Web of Science and Scopus were searched on 23 March 2021 (since inception) and the Cochrane Library on 24 March 2021 (since inception). An initial search strategy was developed for MEDLINE, which was then adapted for other databases. An additional search with the same strategy was performed on 26 July 2022. No publication status or language restrictions were set, but only articles in languages understood by at least one member of the

study team were reviewed. Reading knowledge of the study team members involved in abstract and full-text assessment is as follows: KT—English, Russian and Ukrainian, ARB—English, Russian and German, JK—English and Russian, AF—English, French and Italian, OK—English, Russian and Ukrainian, JS—English and Russian. Although the initial search strategy was unlimited, letters, commentaries, editorials, case studies, case-series with <10 cases and reviews were subsequently excluded.

The electronic search strategy is presented in online supplemental file 1.

Systematic reviews, set aside in the full-text review phase, served as a source of potentially eligible original studies. In addition, the references of publications included in reviews were screened for additional reports of the same study and other relevant studies.

Definitions and study groups

We included studies where the diagnosis of AMI was based on clinical data, imaging (CT or angiography), and laparotomy and/or autopsy report as reported in the original study. During the review process, the studies were categorised as to whether they included patients with all forms of AMI, or patients only with occlusive arterial AMI, MVT or NOMI.

Subgroups

Further, the studies were classified according to patient selection as follows:

- Independent of management—studies including all patients independent of applied treatments, including no treatment.
- Operated patients—studies including only patients who underwent surgery for AMI (with or without revascularisation, including explorative laparotomy/laparoscopy).
- Revascularised patients—studies including only patients with revascularisation (endovascular, open or combined).

Selection of studies and assessment of the risk of bias

Records retrieved from the predefined electronic databases were merged and duplicates removed. The publications were first screened by title and abstract. Full texts of all potentially eligible publications were retrieved and read. Studies were included in the review when all the predefined inclusion criteria were met. Study characteristics were extracted, and their methodological quality assessed according to the Newcastle-Ottawa Scale (NOS).¹¹ We modified the scale as follows: first, under the Selection category the representativeness of the study population was evaluated instead of ‘exposed cohort’, while the selection of the non-exposed cohort and ascertainment of exposure were omitted. Thus, for this category, instead of four stars a study could receive a maximum of two stars. Second, when evaluating the Outcome category, we looked at the adequacy of follow-up of the study population instead of cohorts. Thus, the maximum total number

of stars available was seven. Studies were considered at low risk of bias when receiving four or more stars.

For review, data extraction and quality assessment, standard forms were developed and used. All abstracts were reviewed by two independent researchers, whereas full-text articles were reviewed by one researcher and checked by the second reviewer when creating evidence tables for different outcomes. In the case of uncertainty or discrepancy at any step, consensus of the two researchers had to be reached, after consulting a third researcher if necessary.

Data synthesis

Random-effects meta-analyses were used to combine the estimates of AMI incidence, mortality and proportions in subgroups. Random-effects meta-analysis was preferred due to assumption that observed estimates of treatment effect vary across studies because of real differences in treatment effect in each study as well as sampling variability. By default, generic inverse variance was used for pooling the studies. If subgroup analyses were needed, the generalised linear mixed models method was used instead.

For incidence meta-analysis incidence per 100 000 person years was used. For outcomes of AMI and its different forms, proportion (in %) of all events was used.

The results are presented using forest plots along with I^2 statistic, τ^2 and Cochran's Q-test to describe the heterogeneity. To compare two meta-analysis estimates, random-effects meta-regression was used.

If 95% CIs on incidence estimates were lacking for $N < 15$, the exact method was used.¹²

Analyses were performed using R software (V.4.1.0, R Foundation for Statistical Computing, Vienna, Austria).

Detailed description of data synthesis is presented in online supplemental file 2.

Patient and public involvement

Patients and the general public were not involved in the design or planning of the study.

RESULTS

Literature search and quality assessment

After removal of duplicates, 2591 records were obtained from the initial search, and an additional 178 records were identified through other sources, making 3064 potentially eligible articles (figure 1). On screening the titles and abstracts, 2729 records were excluded, leaving 335 studies for full-text assessment. Review of these articles excluded 172 of them for various reasons (figure 1). Twelve articles were systematic reviews; thus 163 were considered eligible for quantitative synthesis (meta-analysis): 152 retrospective and 11 prospective studies.

All studies included in meta-analyses received more than four points on the modified NOS, indicating low risk of bias (see online supplemental table 1). This is accounted for by the robustness of the outcomes we studied (AMI and mortality) and on the assumption that most patients with AMI were detected.

Four articles in Chinese were excluded as no member of the study team has command of this language.

Incidence of AMI and proportions of its different forms

General population

We found five studies (one of them a series of studies)^{13–16} that addressed the incidence of AMI in the general

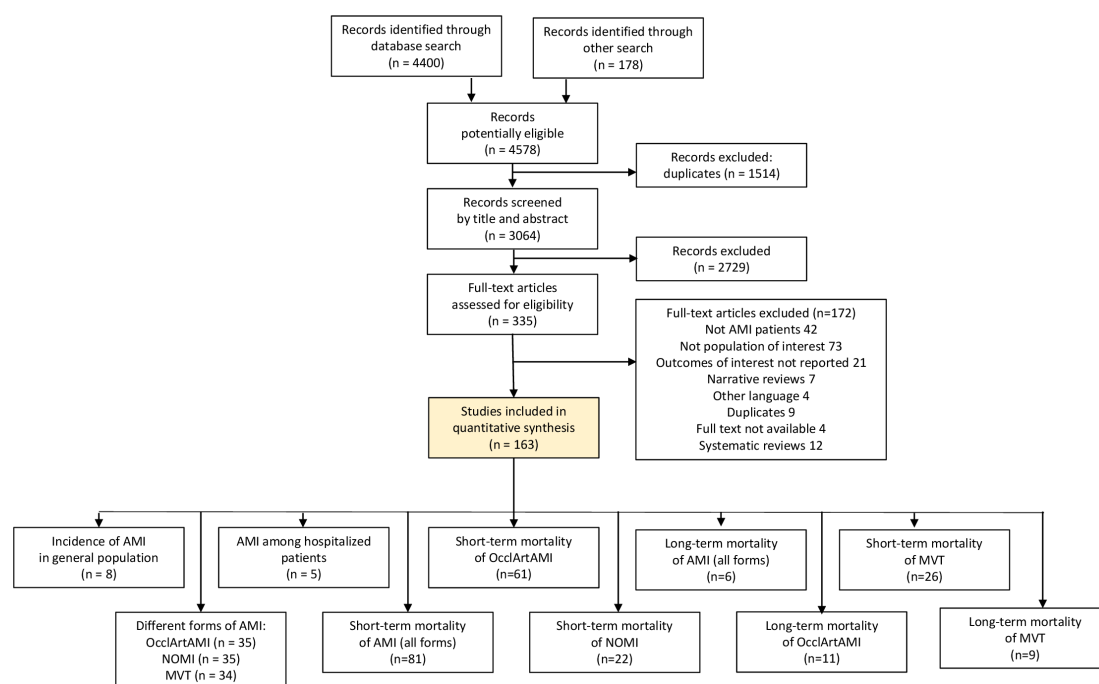


Figure 1 Flow diagram showing the selection of studies included in the review. AMI, acute mesenteric ischaemia; MVT, mesenteric vein thrombosis; OcclArtAMI, occlusive arterial AMI.

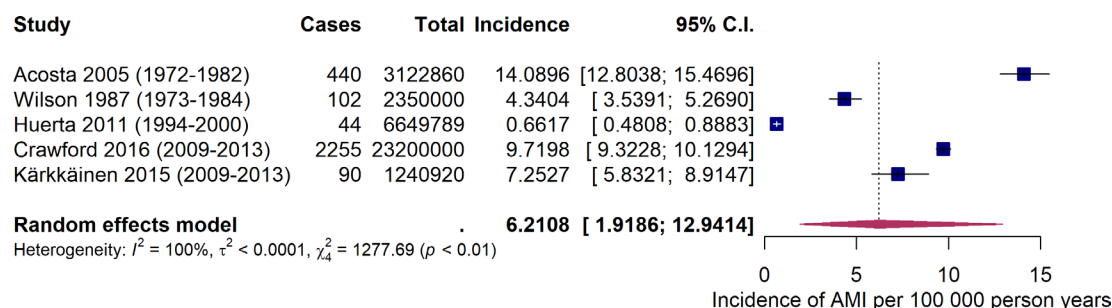


Figure 2 Incidence of acute mesenteric ischaemia in general population, cases per 100 000 person years.

population (figure 2).^{13–20} Among them, only one study reported a population-wide autopsy rate (87%).^{13–16}

On average 6.2 (95% CI 1.9 to 12.9), new cases of AMI were diagnosed annually per 100 000 inhabitants. These studies cover 1970–2013 and are exclusively from high income countries.

It was not possible to perform quantitative synthesis on the incidence of different forms of AMI in general populations. This was, however, reported in the investigation of the population of Malmö, Sweden, in the years 1970–1982, and in a study from Finland, investigating the population of Kuopio in the years 2009–2013. They report 8.6 (95% CI 7.6 to 9.7) and 4.5 (95% CI 2.5 to 8.1) cases of occlusive arterial AMI, 2.0 (95% CI 1.5 to 2.5) and 2.0 (95% CI 0.8 to 4.8) cases of NOMI, and 1.8 (95% CI 1.3 to 2.2) and 0.5 (95% CI 0.21.1) cases of MVT per 100 000 person years, respectively.^{14–16 20}

Thirty-eight studies reported the proportions of different forms of AMI in their cohorts.^{14 17 21–56} Quantitative analysis demonstrates that the most common form is occlusive arterial, constituting 68.6% (95% CI 63.7 to 73.2) of all AMI cases (online supplemental figure 1). NOMI accounts for 15.1% (95% CI 11.8 to 18.7) and MVT for 11.5% (95% CI 9.1 to 14.2) of cases. Arterial occlusion was roughly equally thrombotic and embolic (30.0% (95% CI 24.4 to 36.3) and 33.3% (95% CI 27.3 to 39.9) of all AMI cases, respectively), some studies simply reporting occlusive arterial AMI without distinguishing between the two.

Retrieved data were insufficient for quantitative synthesis of the incidence in different age groups. Single studies indicate that the occurrence of AMI increases with age. Acosta *et al* showed that in Swedish population occlusive arterial AMI increases dramatically with age in both

men and women, reaching 85.8 (95% CI 61.5 to 110.0) per 100 000 person years at age 80–84 years, and 189.5 (95% CI 145.1 to 233.9) in those over 85 years, respectively.¹⁵ Similar exponential growth of all forms of AMI is demonstrated in the Finnish population, reaching 60 cases per 100 000 person years at ages over 80 years.²⁰ The studies included in our analysis of the incidence in the general population, indicate a significantly higher proportion of women, at 58.3% (95% CI 56.5 to 60.2).^{13–20}

Hospitalised patients

Five studies reported the proportion of patients with AMI among hospitalised patients and were included in the meta-analysis (figure 3).^{19 42 57–59} On average, 5.0 (95% CI 3.3 to 7.1) of 10 000 hospital admissions are due to AMI.

Emergency department patients

A meta-analysis was not possible. A single study demonstrated that 1.4% of patients admitted to an emergency department with abdominal pain suffered from AMI.⁶⁰ Another study reported that 3.6% of patients ≥ 65 years who present to hospital for emergency surgery have intestinal ischaemia.⁶¹

Outcomes of AMI and its different forms

Short-term mortality

In total, 81 studies were included in meta-analysis of short-term mortality of AMI, defined as either in-hospital or within 30-days.^{17 19 22 24–28 32–37 39–43 45 47–52 56–58 60 62–112}

The overall mortality was 59.6% (95% CI 55.5 to 63.6) and was only slightly lower in sub-analysis of the 33 studies, which included patients who had been operated on (figure 4).^{19 24 27 33 35 36 40 41 43 47 51 58 92–111} Short-term mortality was 51.7% (95% CI 37.5 to 65.5) in prospective

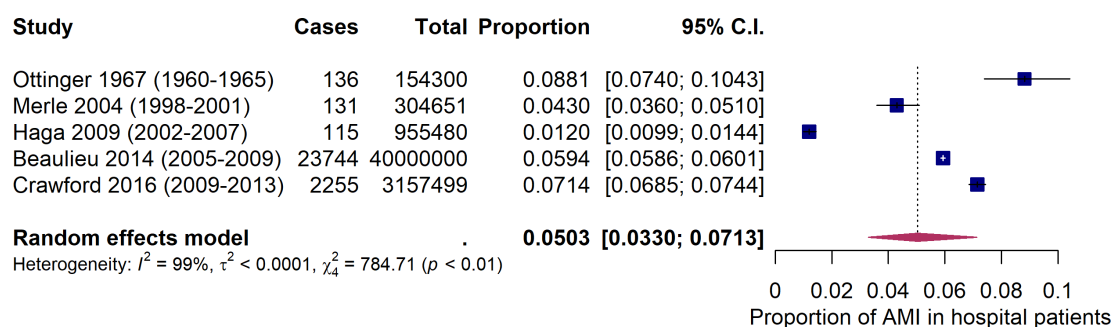


Figure 3 Proportion of patients with acute mesenteric ischaemia (AMI) among hospitalised patients.

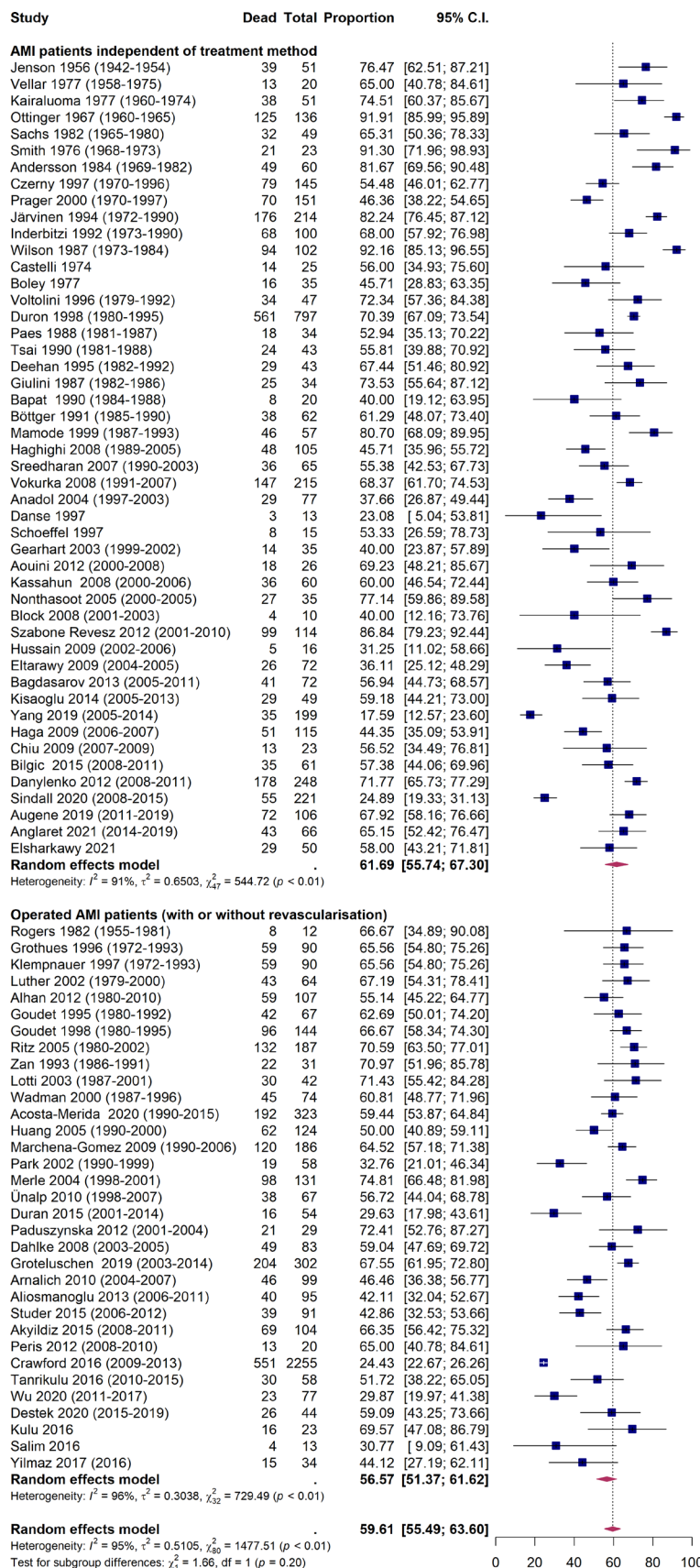


Figure 4 Short-term (hospital or 30 days) mortality of acute mesenteric ischaemia (all forms). Subgroup analyses of studies including all patients independent of treatment method (upper panel) and of studies including only operated patients (lower panel) are presented. In brackets, the period of patient inclusion is indicated. AMI, acute mesenteric ischaemia.

(n=9)^{32 39 49 60 78 82 87 89 112} and 62.9% (95% CI 56.5 to 68.8) in retrospective (n=37)^{17 25 26 28 37 42 45 48 50 57 62–77 79–81 83–86 88 90 91} studies (p=0.15). Table 1 illustrates the evolution of mortality over time. The pooled mortality in the 25 studies from before 2000 including patients independent of treatment method was 68.7% (95% CI 60.8 to 74.9) compared with 55.0% (95% CI 45.5 to 64.1) in the 18 studies where recruitment commenced later (p=0.027) (table 1). Five studies with patients included from both before and after 2000 were excluded from this analysis because the published data did not permit allocation of individuals to one or other era.^{48 75–78} Sensitivity analysis stratifying the studies only according to the date the first patient was enrolled, and thereby including all available studies, showed a difference in mortality from 65.5% to 52.5% (p=0.025).

Sixty-one studies addressed the short-term mortality of occlusive arterial AMI.^{62 225 2731–35 38 39 42 48 49 59 62 63 66 94 95 97 113–153} Meta-analysis showed an overall mortality of 51.8% (95% CI 46.3 to 57.3) (online supplemental figure 2). The sub-analysis of 24 studies on patients who underwent revascularisation demonstrated a mortality of 33.9% (95% CI 30.7 to 37.4).^{6 59 131–148 150–153}

Short-term mortality of patients with NOMI was reported in 22 studies, and 7 of these analyse the outcome of surgery (online supplemental figure 3).^{22 25 27 31–33 35 38 39 42 48 49 93 154–162} The overall mortality of NOMI independent of treatment was 58.4% (95% CI 48.6 to 67.7) and was similar in the studies including operated patients.

Twenty-seven studies reported the short-term outcome of MVT with a pooled mortality rate of 24.6% (17.0–32.9) (online supplemental figure 4).^{22 25 27 31–34 38 39 42 48 49 54 55 62 66 93 116 118 163–170}

Mid-term and long-term mortality

Few studies reported longer outcomes, the follow-up period ranging from 6 months to 5 years. Analysis of six such studies showed 68.2% (95% CI 60.7 to 74.9) overall mortality at a minimum of 6 months (figure 5).^{24 31 41 98 100 171} Eleven studies addressed only occlusive arterial patients with AMI, and meta-analysis demonstrated an overall mid-term/long-term mortality of 59.0% (95% CI 44.9 to 71.7) in this subgroup (figure 6).^{6 121 127 129 131 137 140 144 146 151 172} MVT had better mid/long-term outcome, analysis of nine studies showing a mortality of 28.9% (95% CI 15.2 to 44.8) (figure 7).^{54 163–165 167 169 170 173 174}

DISCUSSION

This systematic review and meta-analysis showed that AMI occurred in 6/100 000 person-years and in 0.05% of hospital admissions. There were considerable differences in the incidences of AMI found in different studies, which might be explained by study methods, evolving of diagnostics over time and autopsy rate. There is likely to be a bias towards underestimation of incidence due to incomplete retrieval of cases detected at autopsy and

low overall autopsy rates in the studied populations.³ In a population-based study conducted between 1970 and 1982 with an autopsy rate of 87%, 79% of patients with occlusive arterial AMI were diagnosed at autopsy.¹⁵ The current proportion of patients not diagnosed in life is very uncertain due to low autopsy rates. In the present review, AMI was more common in women, but the great majority of studies did not control for the longer life expectancy among women in most, if not all, of the studied countries. The different forms of AMI have variable incidence and mortality, with occlusive arterial AMI constituting two thirds of all AMI cases. Revascularised occlusive arterial AMI and MVT carry the best prognosis for survival, but the overall mortality of AMI remains very high, exceeding 50%. The real mortality rate is likely higher, since a substantial number of AMI cases are diagnosed only at autopsy,^{15 17} and the autopsy rate in most studied countries is generally very low, and almost non-existent among the oldest age groups.^{175 176}

Incidence of AMI

The incidence of AMI in the general population and its proportion of hospital admissions have not been assessed in systematic reviews before. The results of this study illustrate the very low incidence of AMI when compared with other cardiovascular diseases such as stroke (up to 265/100 000 person-years)¹⁷⁷ or myocardial infarction (up to 1170/100 000 person-years).¹⁷⁸ Similarly, many other conditions requiring emergency surgery are more common (eg, acute appendicitis: 100/100 000,¹⁷⁹ gastrointestinal bleeding: 19–57/100 000, or perforated peptic ulcer: 4–14/100 000).¹⁸⁰ However, AMI was more common than ruptured abdominal aortic aneurysm, and the age-specific incidence of AMI was higher than the incidence of acute appendicitis in patients over 75 presenting with an acute abdomen.²⁰ The studies included in the present meta-analysis were all retrospective and mostly single-centre studies originating from a wide time span, introducing risks of information bias. There are additional confounding factors, such as changes in demography and diagnostic methods and activity. Accordingly, it is not possible to draw any firm conclusions regarding changes in incidence of AMI over time.

Proportion of different forms of AMI

The great majority of the studies included for analyses of the proportions of different forms of AMI were also retrospective single-centre studies. Additionally, somewhat different definitions of AMI were used, with some studies excluding specific forms such as aortic dissection where others included all cases of AMI independent of mechanism. In our analysis, the forms other than occlusive arterial AMI, MVT and NOMI accounted for <5% of all reported cases of AMI and were not further addressed in detail. However, considering that not all studies considered these 'other' forms at all, the real proportion of 'other' is most probably higher than shown by our analysis. Also, in the literature, there is no uniform consensus

Table 1 Hospital-day or 30-day mortality of acute mesenteric ischaemia in studies including patients treated before or after year 2000

Group	Study	Study years	Died	Number of patients	Mortality (%)
Patients treated before 2000	Jenson and Smith ⁶²	1942–1954	39	51	76.47
	Vellar and Doyle ⁶³	1958–1975	13	20	72.83
	Kairaluoma <i>et al</i> ⁶⁴	1960–1974	38	51	74.51
	Ottinger and Austen ⁵⁷	1960–1965	125	136	91.91
	Sachs <i>et al</i> ²²	1965–1980	32	49	65.31
	Patterson ⁶⁵	1968–1973	21	23	91.30
	Andersson <i>et al</i> ⁶⁶	1969–1982	49	60	81.67
	Czerny <i>et al</i> ²⁵	1970–1996	79	145	54.48
	Prager <i>et al</i> ²⁶	1970–1997	70	151	46.36
	Järvinen <i>et al</i> ⁶⁷	1972–1990	176	214	82.24
	Inderbitzi <i>et al</i> ²⁸	1973–1990	68	100	68.00
	Wilson <i>et al</i> ¹⁷	1973–1984	94	102	92.16
	Castelli <i>et al</i> ⁶⁸	n/a	14	25	56.00
	Boley <i>et al</i> ³²	n/a	16	35	45.71
	Voltolini <i>et al</i> ³⁴	1979–1992	34	47	72.34
	Duron <i>et al</i> ⁶⁹	1980–1995	561	797	70.39
	Paes <i>et al</i> ³⁷	1981–1987	18	34	52.94
	Tsai <i>et al</i> ⁷⁰	1981–1988	24	43	55.81
	Deehan <i>et al</i> ⁷¹	1982–1992	29	43	67.44
	Giulini <i>et al</i> ⁷²	1982–1986	25	34	73.53
	Bapat <i>et al</i> ⁷³	1984–1988	8	20	40.00
	Böttger <i>et al</i> ³⁹	1985–1990	38	62	61.29
	Mamode <i>et al</i> ⁷⁴	1987–1993	46	57	80.70
	Danse <i>et al</i> ⁶⁰	n/a	3	13	23.08
	Schoeffel <i>et al</i> ⁴⁹	n/a	8	15	53.33
	Subtotal		1628	2276	
	Mortality (95% CI)			68.67 (60.78 to 74.91)	
Patients treated after 2000	Aouini <i>et al</i> ⁷⁹	2000–2008	18	26	69.23
	Kassahun <i>et al</i> ⁸⁰	2000–2006	36	60	60.00
	Nonthasoot <i>et al</i> ⁸¹	2000–2005	27	35	77.14
	Block <i>et al</i> ⁸²	2001–2003	4	10	40.00
	Szabone Revesz ⁵⁰	2001–2010	99	114	86.84
	Hussain <i>et al</i> ⁸³	2002–2006	5	16	31.25
	Eltarawy <i>et al</i> ⁸⁴	2004–2005	26	72	36.11
	Bagdasarov <i>et al</i> ⁴⁵	2005–2011	41	72	56.94
	Kisaoglu <i>et al</i> ⁸⁵	2005–2013	29	49	59.18
	Yang <i>et al</i> ⁸⁶	2005–2014	35	199	17.59
	Haga <i>et al</i> ⁴²	2006–2007	51	115	44.35
	Chiu <i>et al</i> ⁸⁷	2007–2009	13	23	56.52
	Bilgic <i>et al</i> ⁸⁸	2008–2011	35	61	57.38
	Danylenko <i>et al</i> ⁸⁹	2008–2011	178	248	51.90
	Sindall <i>et al</i> ⁹⁰	2008–2015	55	221	24.89
	Augene <i>et al</i> ⁹¹	2011–2019	72	106	67.92
	Anglaret <i>et al</i> ⁵⁶	2014–2019	43	66	65.15

Continued

Table 1 Continued

Group	Study	Study years	Died	Number of patients	Mortality (%)
	Elsharkawy <i>et al</i> ¹¹²		29	50	58.00
	Subtotal		796	1543	
	Mortality (95% CI)			54.97 (45.53 to 64.06)	
				p=0.0266	

about the forms of mesenteric ischaemia that should be included in the definition of AMI. For example, the World Society of Emergency Surgery guidelines suggest considering only interruption of the blood supply to the small bowel in their definition of AMI, which is unfortunate since the superior mesenteric artery typically supplies not only the distal part of the duodenum and small bowel but also the large bowel up to the mid transverse colon, and NOMI may affect any part of the intestine as well as being responsible for extra-intestinal organ ischaemia.^{14 181} At the same time, the European Society of Vascular Surgery guidelines include acute colonic ischaemia, pointing out that acute colonic ischaemia is often erroneously labelled as ischaemic colitis.² In present study, colonic ischaemia and/or ischaemic colitis were not included as specific key words in the literature search. Retrieved papers reporting acute inferior mesenteric artery ischaemia among all other forms of AMI were, however, included in the analysis.

Outcomes of AMI

Whereas outcomes of other vascular catastrophes such as acute coronary syndrome and stroke have improved substantially during the past few decades, the mortality after AMI remains high, although with some improvement observed. However, it remains possible that selection bias due to less consistent reporting of cases

diagnosed post-mortem in more recent decades plays a role in this finding. The mortality data in the present review are, however, in accordance with two earlier systematic reviews. Inclusion of 78 studies from 1956 to 2020 in the present analysis leads to a pooled mortality of 59%, while Schoots *et al*⁴ calculated a pooled in-hospital mortality of 73% from 47 studies published from 1967 to 2002, and Adaba *et al*⁵ 63% from 52 articles published from 1956 to 2012. We were not able to analyse if AMI mortality has changed over the last decade as most of the studies included patients over long periods of time (10 years and more) and only three had cases between years 2012 and 2022.

Different forms of AMI at their different stages are encountered by different specialists and are often studied as separate entities. Thereby, progress in management of specific forms of AMI has been achieved, concerning mainly the endovascular and hybrid therapy of occlusive arterial AMI.^{6 123} In this review, intestinal revascularisation was seen to be associated with an almost halved mortality compared with the overall mortality in patients with occlusive arterial AMI. Considering that occlusive arterial AMI is the most common form of AMI, a larger effect on the reduction of overall mortality could have been expected with the development of endovascular therapy since the turn of the millennium; similarly to Adaba *et*

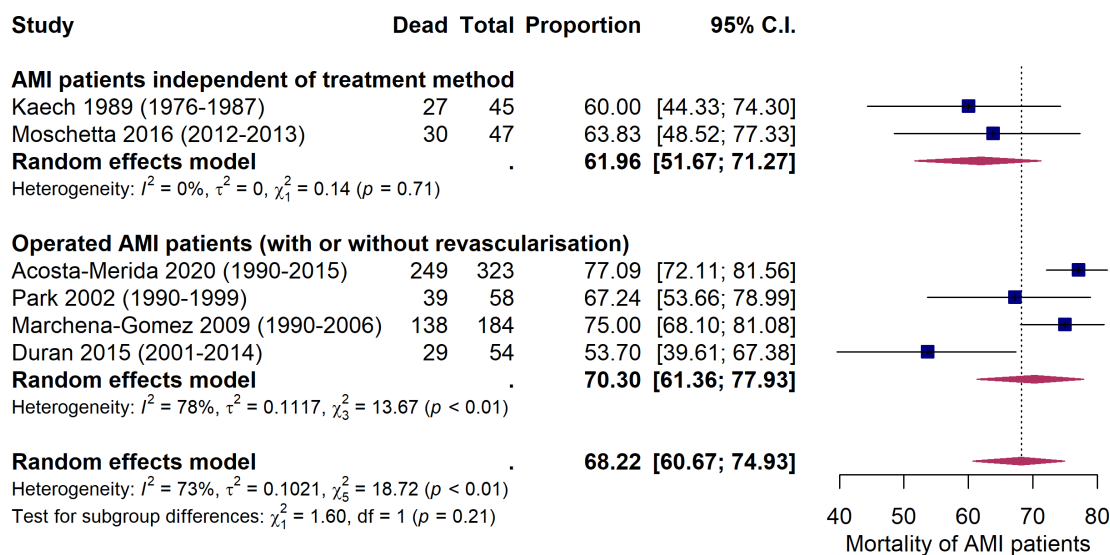


Figure 5 Long-term (6 months to 5 years) mortality of acute mesenteric ischaemia, all forms. Subgroup analyses of studies including patients independent of treatment method (upper panel) and of studies including only operated patients (lower panel) are presented. In brackets, the period of patient inclusion is indicated. AMI, acute mesenteric ischaemia.

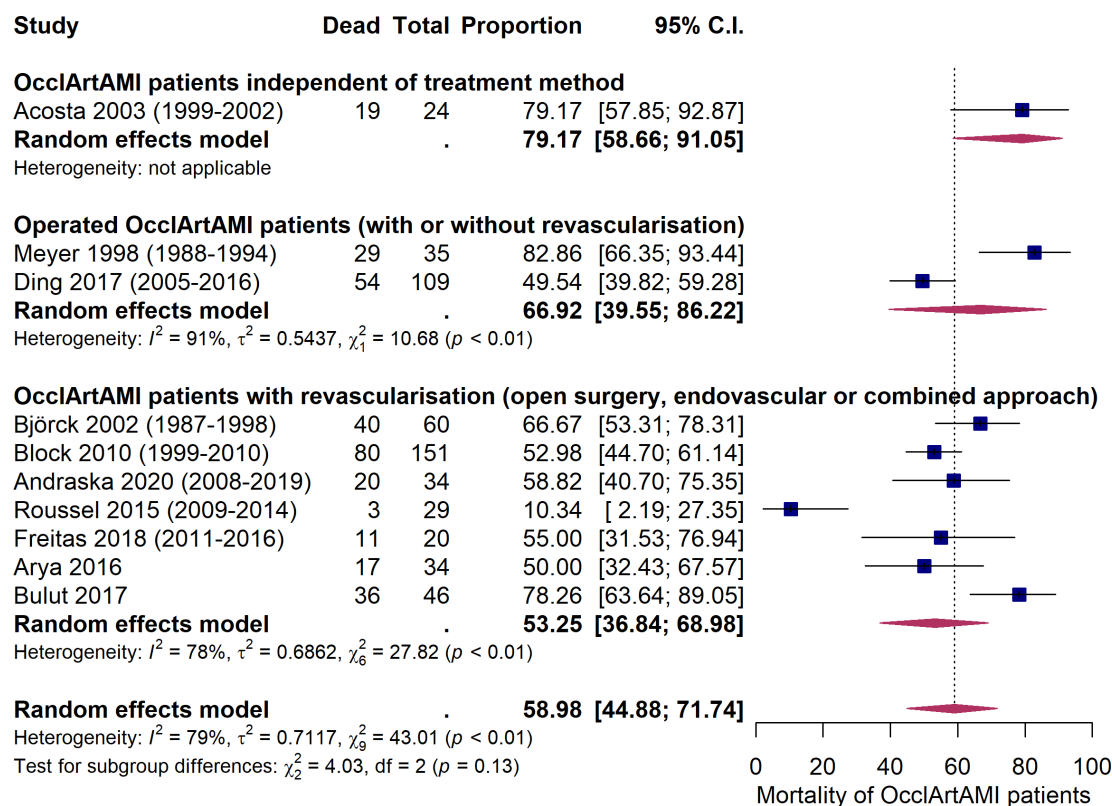


Figure 6 Long-term (6 months to 5 years) mortality of occlusive arterial acute mesenteric ischaemia (OcclArtAMI). Subgroup analyses of studies including patients independent of treatment method (upper panel), of studies including only operated patients (middle panel), and of studies including only patients with revascularisation (lower panel) are presented. In brackets, the period of patient inclusion is indicated.

at⁵ we showed only a modest reduction. Late diagnosis despite round-the-clock availability of contrast-enhanced computed tomography (at least in high-income countries) contributes to the continued low rate of intestinal revascularisation and high mortality in patients with occlusive arterial AMI. This explanation is supported by two studies using data from a large nationwide database, reporting attempted revascularisation rates of only 2.9–4.2%.^{59 136} As clinical signs of AMI are non-specific and reliable specific biomarkers are lacking, the diagnosis is often delayed resulting in progression of intestinal

ischaemia to transmural intestinal necrosis and peritonitis before the diagnosis is made.^{84 121}

In this systematic review, we only focused on survival outcome, as data on other patient-relevant outcomes (presence of stoma, need of parenteral nutrition, quality of life) are scarce, justifying future prospective studies. We also omitted analysis of hospital length of stay, although this was initially planned, because it was greatly influenced by early and very high mortality, as well as lack of data. These outcomes are important, however, and should be considered when comparing different treatment methods.

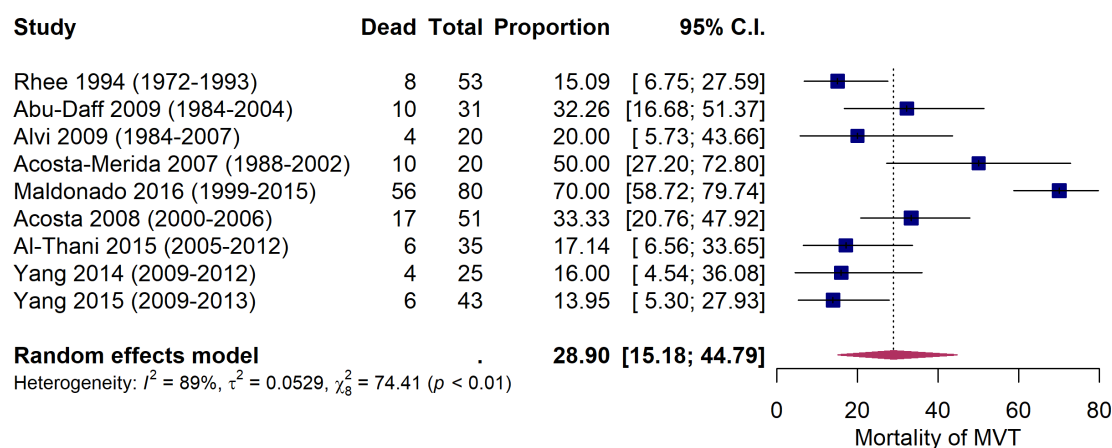


Figure 7 Long-term (2 months to 5 years) mortality of mesenteric vein thrombosis (MVT). In brackets, the period of patient inclusion is indicated.

Mid-term to long-term mortality was only slightly higher than short-term mortality in our analysis, suggesting that a high proportion of the patients surviving initial hospitalisation for AMI, actually have a favourable prognosis.

Strengths and limitations

This study has supplied data to assist in the planning of a prospective multicentre study (ClinTrials number NCT05218863).¹⁸² The aim of this planned study is to identify the incidence and outcome of AMI in hospitalised patients, describe clinical and laboratory variables of different forms of AMI at baseline and map the patterns of diagnosis and management. This international research programme should contribute to development of an algorithm for diagnosis and management of AMI. We believe that obtaining an overall picture of AMI rather than focusing on each form of AMI separately is needed to increase knowledge and awareness among physicians and ultimately to improve outcome. The main strength of the present study is provision of a broad overview of the existing literature on AMI. Among the limitations are: (1) by not including the term ‘colonic ischaemia’ or the misnomer ‘ischaemic colitis’ in the search strategy we might have missed some studies on AMI. However, reporting in articles is almost exclusively based on the forms of AMI differentiated based on pathophysiological mechanism, while both the small and large bowel are often affected in occlusive arterial AMI and NOMI; (2) the long study periods and single-centre retrospective nature of most of the studies, where the evidence can only be improved by future studies; (3) the pooling of studies with somewhat different definitions and management algorithms, where we created categories to minimise these differences; (4) the inherent risk of bias, both publication bias of the studies, and possible bias in the assessment of the studies, although no efforts were spared to avoid this.

In summary, the present systematic analysis estimated the incidence of AMI in the general population and hospitalised patients, forming basis for planning of future prospective studies. Two thirds of AMI cases are of occlusive arterial origin with the potential for better survival, if diagnosed promptly and revascularised in time. AMI due to MVT carries the best spontaneous prognosis. Despite some progress in revascularisation techniques, and improved survival since the millennium, emergency revascularisation rates remain low and mortality remains very high. There is great potential for future improvement.

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REFERENCES

- Oldenburg WA, Lau LL, Rodenberg TJ, *et al.* Acute mesenteric ischemia: a clinical review. *Arch Intern Med* 2004;164:1054–62.
- Björck M, Koelemay M, Acosta S. Clinical practice guidelines of the European Society of vascular surgery (ESVS). *Eur J Vasc Endovasc Surg* 2017;53:460–510.
- Acosta S. Epidemiology of mesenteric vascular disease: clinical implications. *Semin Vasc Surg* 2010;23:4–8.
- Schoots IG, Koffeman GI, Legemate DA, *et al.* Systematic review of survival after acute mesenteric ischaemia according to disease aetiology. *Br J Surg* 2004;91:17–27.
- Adaba F, Askari A, Dastur J, *et al.* Mortality after acute primary mesenteric infarction: a systematic review and meta-analysis of observational studies. *Colorectal Dis* 2015;17:566–77.
- Roussel A, Castier Y, Nuzzo A, *et al.* Revascularization of acute mesenteric ischemia after creation of a dedicated multidisciplinary center. *J Vasc Surg* 2015;62:1251–6.

- 7 Corcos O, Castier Y, Sibert A, *et al.* Effects of a multimodal management strategy for acute mesenteric ischemia on survival and intestinal failure. *Clin Gastroenterol Hepatol* 2013;11:158–65.
- 8 Tolonen M, Lemma A, Vikatmaa P, *et al.* The implementation of a pathway and care bundle for the management of acute occlusive arterial mesenteric ischemia reduced mortality. *J Trauma Acute Care Surg* 2021;91:480–8.
- 9 Page MJ, McKenzie JE, Bossuyt PM, *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
- 10 The World Bank. World bank country and lending groups. Washington DC: the world bank, 2021. Available: <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups> [Accessed 17 Feb 2022].
- 11 Wells GA, Shea B, O'Connell D, *et al.* The Newcastle-Ottawa scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Available: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp [Accessed 17 Feb 2022].
- 12 Armitage P, Berry G. *Statistical methods in medical research*. 2nd ed. Oxford: Blackwell Scientific Publications, 1987.
- 13 Acosta S, Ögren M, Sternby N-H, *et al.* Fatal colonic ischemia: a population-based study. *Scand J Gastroenterol* 2006;41:1312–9.
- 14 Acosta S, Ögren M, Sternby N-H, *et al.* Fatal nonocclusive mesenteric ischaemia: population-based incidence and risk factors. *J Intern Med* 2006;259:305–13.
- 15 Acosta S, Ögren M, Sternby N-H, *et al.* Incidence of acute thrombo-embolic occlusion of the superior mesenteric artery—a population-based study. *Eur J Vasc Endovasc Surg* 2004;27:145–50.
- 16 Acosta S, Ögren M, Sternby N-H, *et al.* Mesenteric venous thrombosis with transmural intestinal infarction: a population-based study. *J Vasc Surg* 2005;41:59–63.
- 17 Wilson C, Gupta R, Gilmour DG, *et al.* Acute superior mesenteric ischaemia. *Br J Surg* 1987;74:279–81.
- 18 Huerta C, Rivero E, Montoro MA, *et al.* Risk factors for intestinal ischaemia among patients registered in a UK primary care database: a nested case-control study. *Aliment Pharmacol Ther* 2011;33:969–78.
- 19 Crawford RS, Harris DG, Klyushnenkova EN, *et al.* A statewide analysis of the incidence and outcomes of acute mesenteric ischemia in Maryland from 2009 to 2013. *Front Surg* 2016;3:22.
- 20 Kärkkäinen JM, Lehtimäki TT, Manninen H, *et al.* Acute mesenteric ischemia is a more common cause than expected of acute abdomen in the elderly. *J Gastrointest Surg* 2015;19:1407–14.
- 21 Hansen HJ, Christoffersen JK. Occlusive mesenteric infarction. A retrospective study of 83 cases. *Acta Chir Scand Suppl* 1976;472:103–8.
- 22 Sachs SM, Morton JH, Schwartz SI. Acute mesenteric ischemia. *Surgery* 1982;92:646–53.
- 23 Clavien PA, Dürig M, Harder F. Venous mesenteric infarction: a particular entity. *Br J Surg* 1988;75:252–5.
- 24 Acosta-Mérida MA, Marchena-Gómez J, Saavedra-Santana P, *et al.* Surgical outcomes in acute mesenteric ischemia: has anything changed over the years? *World J Surg* 2020;44:100–7.
- 25 Czerny M, Trubel W, Claeys L. [Acute mesenteric ischemia]. *Zentralblatt fuer Chirurgie* 1997;122:538–44. German.
- 26 Prager M, Teufelsbauer H, Nanobashvili J, *et al.* [Abdominal vascular surgery emergencies: abdominal aortic aneurysm, acute mesenteric ischemia—indications, technique, results]. *Acta Med Austriaca* 2000;27:145–51. German.
- 27 Grothues F, Bektas H, Klempnauer J. [Surgical therapy of acute mesenteric ischemia]. *Langenbecks Arch Chir* 1996;381:275–82. German.
- 28 Inderbitzi R, Wagner HE, Seiler C, *et al.* Acute mesenteric ischaemia. *Eur J Surg* 1992;158:123–6.
- 29 Boos S. [Angiography of the mesenteric artery 1976 to 1991. A change in the indications during mesenteric circulatory disorders?]. *Radiologe* 1992;32:154–7. German.
- 30 Clark RA, Gallant TE. Acute mesenteric ischemia: angiographic spectrum. *AJR Am J Roentgenol* 1984;142:555–62.
- 31 Käch K, Largiadèr F. [Acute mesenteric infarcts—results of surgical therapy]. *Helv Chir Acta* 1989;56:23–7. German.
- 32 Boley SJ, Sprayregen S, Siegelman SS, *et al.* Initial results from an aggressive roentgenological and surgical approach to acute mesenteric ischemia. *Surgery* 1977;82:848–55.
- 33 Luther B, Moussazadeh K, Müller BT. Die akute mesenteriale Ischämie - unverständlich oder unheilbar? [The acute mesenteric ischemia - not understood or incurable?]. *Zentralbl Chir* 2002;127:674–84. German.
- 34 Voltolini F, Pricolo R, Naldini G. Ischemia mesenterica acuta. Analisi di 47 casi [Acute mesenteric ischemia. Analysis of 47 cases]. *Minerva Chir* 1996;51:285–92.
- 35 Alhan E, Usta A, Çekiç A, *et al.* A study on 107 patients with acute mesenteric ischemia over 30 years. *Int J Surg* 2012;10:510–3.
- 36 Ritz J-P, Germer C-T, Buhr HJ. Prognostic factors for mesenteric infarction: multivariate analysis of 187 patients with regard to patient age. *Ann Vasc Surg* 2005;19:328–34.
- 37 Paes E, Vollmar JF, Hutschenreiter S. Der Mesenterialinfarkt. Neue Aspekte der Diagnostik und Therapie [Mesenterial infarct. New aspects of diagnosis and therapy]. *Chirurg* 1988;59:828–35.
- 38 Gawenda M, Scherwitz P, Walter M. Letalitätsfaktoren des Darminfarkts primär vaskulärer Genese [Fatal outcome factors of intestinal infarct of primary vascular origin]. *Langenbecks Arch Chir* 1997;382:319–24. German.
- 39 Böttger T, Jonas J, Weber W. Sensitivität der präoperativen Diagnostik beim Mesenterialgefäßverschluss [Sensitivity of preoperative diagnosis in mesenteric vascular occlusion]. *Bildgebung* 1991;58:192–8. German.
- 40 Huang H-H, Chang Y-C, Yen DH-T, *et al.* Clinical factors and outcomes in patients with acute mesenteric ischemia in the emergency department. *J Chin Med Assoc* 2005;68:299–306.
- 41 Park WM, Gloviczki P, Cherry KJ, *et al.* Contemporary management of acute mesenteric ischemia: factors associated with survival. *J Vasc Surg* 2002;35:445–52.
- 42 Haga Y, Odo M, Homma M, *et al.* New prediction rule for mortality in acute mesenteric ischemia. *Digestion* 2009;80:104–11.
- 43 Dahlke MH, Asshoff L, Popp FC, *et al.* Mesenteric ischemia—outcome after surgical therapy in 83 patients. *Dig Surg* 2008;25:213–9.
- 44 Baeshko AA, Klumuk SA, Iushkevich VA. Acute disorders of mesenteric circulations: the etiology, risk factors and incidence of lesions. *Angiol Sosud Khir* 2004;10:99–113. English, Russian.
- 45 Bagdasarov VV, Bagdasarova EA, Chernookov AI. [Tactics by the acute intestinal ischemia]. *Khirurgiya* 2013;6:44–50. Russian.
- 46 Nuzzo A, Maggiori L, Ronot M, *et al.* Predictive factors of intestinal necrosis in acute mesenteric ischemia: prospective study from an intestinal stroke center. *Am J Gastroenterol* 2017;112:597–605.
- 47 Destek S, Yabacı A, Abik YN, *et al.* Predictive and prognostic value of L-lactate, D-dimer, leukocyte, C-reactive protein and neutrophil/lymphocyte ratio in patients with acute mesenteric ischemia. *Ulus Travma Acil Cerrahi Derg* 2020;26:86–94.
- 48 Sreedharan S, Tan YM, Tan SG, *et al.* Clinical spectrum and surgical management of acute mesenteric ischaemia in Singapore. *Singapore Med J* 2007;48:319–23.
- 49 Schoeffel U, Baumgartner U, Imdahl A, *et al.* The influence of ischemic bowel wall damage on translocation, inflammatory response, and clinical course. *Am J Surg* 1997;174:39–44.
- 50 Szabóné Révész E. Akut mesenterialis ischaemia: 10 év eseteinek elemzése (2001–2010) [Acute mesenteric ischemia: analysis of cases over a ten-years period (2001–2010)]. *Orv Hetil* 2012;153:1424–32. Hungarian.
- 51 Arnalich F, Maldifassi MC, Ciria E, *et al.* Association of cell-free plasma DNA with perioperative mortality in patients with suspected acute mesenteric ischemia. *Clin Chim Acta* 2010;411:1269–74.
- 52 Akyıldız HY, Sözüer E, Uzer H, *et al.* The length of necrosis and renal insufficiency predict the outcome of acute mesenteric ischemia. *Asian J Surg* 2015;38:28–32.
- 53 Calame P, Malakhia A, Turco C, *et al.* Transmural bowel necrosis from acute mesenteric ischemia and strangulated small-bowel obstruction: distinctive CT features. *AJR Am J Roentgenol* 2020;214:90–5.
- 54 Abu-Daff S, Abu-Daff N, Al-Shahed M. Mesenteric venous thrombosis and factors associated with mortality: a statistical analysis with five-year follow-up. *J Gastrointest Surg* 2009;13:1245–50.
- 55 Brunaud L, Antunes L, Collinet-Adler S, *et al.* Acute mesenteric venous thrombosis: case for nonoperative management. *J Vasc Surg* 2001;34:673–9.
- 56 Anglaret S, Dallongeville A, Beaussier H, *et al.* Influence of clinical suspicion on CT accuracy of acute mesenteric ischemia: retrospective study of 362 patients. *Eur J Radiol* 2021;138:109652.
- 57 Ottinger LW, Austen WG. A study of 136 patients with mesenteric infarction. *Surg Gynecol Obstet* 1967;124:251–61.
- 58 Merle C, Lepouse C, De Garine A, *et al.* Surgery for mesenteric infarction: prognostic factors associated with early death within 72 hours. *J Cardiothorac Vasc Anesth* 2004;18:734–41.
- 59 Beaulieu RJ, Arnaoutakis KD, Abularrage CJ, *et al.* Comparison of open and endovascular treatment of acute mesenteric ischemia. *J Vasc Surg* 2014;59:159–64.
- 60 Danse EM, Laterre PF, Van Beers BE, *et al.* Early diagnosis of acute intestinal ischaemia: contribution of colour Doppler sonography. *Acta Chir Belg* 1997;97:173–6.

- 61 Guttman MP, Tillmann BW, Nathens AB, *et al.* Alive and at home: five-year outcomes in older adults following emergency general surgery. *J Trauma Acute Care Surg* 2021;90:287–95.
- 62 Jensen CB, Smith GA. A clinical study of 51 cases of mesenteric infarction. *Surgery* 1956;40:930–7.
- 63 Vellar ID, Doyle JC. Acute mesenteric ischaemia. *Aust N Z J Surg* 1977;47:54–61.
- 64 Kairaluoma MI, Heikkinen D, Karkola P, *et al.* Mesenteric infarction. *Am J Surg* 1977;133:188–93.
- 65 Patterson LT. Acute mesenteric infarction. *Am Surg* 1976;42.
- 66 Andersson R, Pärsson H, Isaksson B, *et al.* Acute intestinal ischemia. A 14-year retrospective investigation. *Acta Chir Scand* 1984;150:217–21.
- 67 Jrvinen O, Laurikka J, Salenius JP, *et al.* Acute intestinal ischaemia. A review of 214 cases. *Ann Chir Gynaecol* 1994;83:22–5.
- 68 Castelli MF, Qizilbash AH, Fyshe TG. Ischemic bowel disease. *Can Med Assoc J* 1974;111:935–6, 939–41.
- 69 Duron JJ, Peyrard P, Boukhtouche S. Ischémie mésentérique aiguë: ce qui a changé durant la décennie 1985-1995. Associations de recherche en chirurgie [Acute mesenteric ischemia: changes in 1985-1995. Surgical Research Associations]. *Chirurgie* 1998;123:335–42. French.
- 70 Tsai CJ, Kuo YC, Chen PC, *et al.* The spectrum of acute intestinal vascular failure: a collective review of 43 cases in Taiwan. *Br J Clin Pract* 1990;44:603–8.
- 71 Deehan DJ, Heys SD, Brittenden J, *et al.* Mesenteric ischaemia: prognostic factors and influence of delay upon outcome. *J R Coll Surg Edinb* 1995;40:112–5.
- 72 Giulini S, Bonardelli S, Cangiotti L, *et al.* Factors affecting prognosis in acute intestinal ischemia. *Int Angiol* 1987;6:415–20.
- 73 Bapat RD, Aiyer PM, Relekar RG, *et al.* Ischemic bowel disease. *Indian J Gastroenterol* 1990;9:19–22.
- 74 Mamode N, Pickford I, Leiberman P. Failure to improve outcome in acute mesenteric ischaemia: seven-year review. *Eur J Surg* 1999;165:203–8.
- 75 Haghighi PH, Lankarani KB, Taghavi SA, *et al.* Acute mesenteric ischemia: causes and mortality rates over sixteen years in southern Iran. *Indian J Gastroenterol* 2008;27:236–8.
- 76 Vokurka J, Olejnik J, Jedlicka V, *et al.* Acute mesenteric ischemia. *Hepatogastroenterology* 2008;55:1349–52.
- 77 Anadol AZ, Ersoy E, Taneri F, *et al.* Laparoscopic "second-look" in the management of mesenteric ischemia. *Surg Laparosc Endosc Percutan Tech* 2004;14:191–3.
- 78 Gearhart SL, Delaney CP, Senagore AJ, *et al.* Prospective assessment of the predictive value of alpha-glutathione S-transferase for intestinal ischemia. *Am Surg* 2003;69:324–9.
- 79 Aouini F, Bouhaffa A, Baazaoui J. Ischémie mésentérique aiguë : Etude des facteurs prédictifs de mortalité [Acute mesenteric ischemia: study of predictive factors of mortality]. *Tunis Med* 2012;90:533–6. French.
- 80 Kassahun WT, Schulz T, Richter O, *et al.* Unchanged high mortality rates from acute occlusive intestinal ischemia: six year review. *Langenbecks Arch Surg* 2008;393:163–71.
- 81 Nonthasoot B, Tullavardhana T, Sirichindakul B, *et al.* Acute mesenteric ischemia: still high mortality rate in the era of 24-hour availability of angiography. *J Med Assoc Thai* 2005;88 Suppl 4:S46–50.
- 82 Block T, Nilsson TK, Björck M, *et al.* Diagnostic accuracy of plasma biomarkers for intestinal ischaemia. *Scand J Clin Lab Invest* 2008;68:242–8.
- 83 Hussain D, Sarfraz SL, Baliga SK, *et al.* Acute mesenteric ischemia: experience in a tertiary care hospital. *J Ayub Med Coll Abbottabad* 2009;21:70–2.
- 84 Eltarawy IG, Etman YM, Zenati M, *et al.* Acute mesenteric ischemia: the importance of early surgical consultation. *Am Surg* 2009;75:212–9.
- 85 Kisaoglu A, Bayramoglu A, Ozogul B, *et al.* Sensitivity and specificity of red cell distribution width in diagnosing acute mesenteric ischemia in patients with abdominal pain. *World J Surg* 2014;38:2770–6.
- 86 Yang S, Zhao Y, Chen J, *et al.* Clinical features and outcomes of patients with acute mesenteric ischemia and concomitant colon ischemia: a retrospective cohort study. *J Surg Res* 2019;233:231–9.
- 87 Chiu Y-H, Huang M-K, How C-K, *et al.* D-Dimer in patients with suspected acute mesenteric ischemia. *Am J Emerg Med* 2009;27:975–9.
- 88 Bilgiç I, Dolu F, Şenol K, *et al.* Prognostic significance of red cell distribution width in acute mesenteric ischemia. *Perfusion* 2015;30:161–5.
- 89 Danylenko IA, Kononenko MH, Leonov VV, *et al.* [The treatment process optimization in patients suffering from acute disorder of mesenteric blood circulation]. *Klin Khir* 2012;12–16. Ukrainian.
- 90 Sindall ME, Davenport DL, Wallace P, *et al.* Validation of the American association for the surgery of trauma grading system for acute mesenteric ischemia—More than anatomic severity is needed to determine risk of mortality. *J Trauma Acute Care Surg* 2020;88:671–6.
- 91 Augène E, Lareyre F, Chikande J, *et al.* Platelet to lymphocyte ratio as a predictive factor of 30-day mortality in patients with acute mesenteric ischemia. *PLoS One* 2019;14:e0219763.
- 92 Rogers DM, Thompson JE, Garrett WV, *et al.* Mesenteric vascular problems. A 26-year experience. *Ann Surg* 1982;195:554–65.
- 93 Klempnauer J, Grothues F, Bektas H, *et al.* Long-Term results after surgery for acute mesenteric ischemia. *Surgery* 1997;121:239–43.
- 94 Goudet P, Tahan H, Sobh A. Les infarctus intestinaux. Une ré-évaluation des facteurs pronostiques de mortalité post-opératoire [Intestinal infarctions. A re-evaluation of prognostic factors of postoperative mortality]. *Ann Chir* 1995;49:607–12. French.
- 95 Goudet P, Michelin T, Rousseau P, *et al.* Intestinal infarctions: a reappraisal of the factors predictive of operative mortality. *Eur J Surg* 1998;164:593–8.
- 96 Zan S, Giustetto A, Mastroianni V. Ischemia intestinale acuta. Diagnosi e trattamento chirurgico [Acute intestinal ischemia. Diagnosis and surgical treatment]. *Minerva Chir* 1993;48:543–8.
- 97 Wadman M, Syk I, Elmståhl S. Survival after operations for ischaemic bowel disease. *Eur J Surg* 2000;166:872–7.
- 98 Marchena-Gomez J, Acosta-Merida MA, Hemmersbach-Miller M, *et al.* The age-adjusted Charlson comorbidity index as an outcome predictor of patients with acute mesenteric ischemia. *Ann Vasc Surg* 2009;23:458–64.
- 99 Unalp HR, Atahan K, Kamer E. Nekroz nedeniyle bağırsak rezeksiyonu uygulanan akut mezenterik iskemili olgularda hastane mortalitesi için prognostik faktörler [Prognostic factors for hospital mortality in patients with acute mesenteric ischemia who undergo intestinal resection due to necrosis]. *Ulus Travma Acil Cerrahi Derg* 2010;16:63–70. Turkish.
- 100 Duran M, Pohl E, Grabitz K, *et al.* The importance of open emergency surgery in the treatment of acute mesenteric ischemia. *World J Emerg Surg* 2015;10:45.
- 101 Paduszynska K, Celnik A, Pomorski L. Patients subject to surgery due to acute abdominal disorders during the period between 2001–2004. *Pol Przegl Chir* 2012;84:488–94.
- 102 Grotelüschen R, Bergmann W, Welte MN, *et al.* What predicts the outcome in patients with intestinal ischemia? a single center experience. *J Visc Surg* 2019;156:405–11.
- 103 Aliosmanoglu I, Gul M, Kapan M, *et al.* Risk factors effecting mortality in acute mesenteric ischemia and mortality rates: a single center experience. *Int Surg* 2013;98:76–81.
- 104 Studer P, Vaucher A, Candinas D, *et al.* The value of serial serum lactate measurements in predicting the extent of ischemic bowel and outcome of patients suffering acute mesenteric ischemia. *J Gastrointest Surg* 2015;19:751–5.
- 105 Peris A, Zagli G, Maccarrone N, *et al.* The use of modified early warning score may help anesthetists in postoperative level of care selection in emergency abdominal surgery. *Minerva Anestesiol* 2012;78:1034–8.
- 106 Tanrikulu Y, Şen Tanrikulu C, Sabuncuoğlu MZ, *et al.* Diagnostic utility of the neutrophil-lymphocyte ratio in patients with acute mesenteric ischemia: a retrospective cohort study. *Ulus Travma Acil Cerrahi Derg* 2016;22:344–9.
- 107 Wu W, Yang L, Zhou Z. Clinical features and factors affecting postoperative mortality for obstructive acute mesenteric ischemia in China: a hospital-based survey. *Vasc Health Risk Manag* 2020;16:479–87.
- 108 Kulu R, Akyildiz H, Akcan A, *et al.* Plasma citrulline measurement in the diagnosis of acute mesenteric ischaemia. *ANZ J Surg* 2017;87:E57–60.
- 109 Salim SY, Young PY, Churchill TA, *et al.* Urine intestinal fatty acid-binding protein predicts acute mesenteric ischemia in patients. *J Surg Res* 2017;209:258–65.
- 110 Yilmaz EM, Carti EB. Prognostic factors in acute mesenteric ischemia and evaluation with Mannheim peritonitis index and platelet-to-lymphocyte ratio. *Ulus Travma Acil Cerrahi Derg* 2017;23:301–5.
- 111 Lotti R, Perri G, Nardi M. La procedura "second-look" nella terapia chirurgica dell'infarto intestinale ["Second-look" in the surgical therapy of mesenteric infarction]. *Chirurgia* 2003;16:163–6.
- 112 NMHY E, Abu Zeid MM, Ahmed MES. Clinical predictors of mortality in acute mesenteric ischemia. *Egypt J Hosp Med* 2021;82:479–86.

- 113 Krausz MM, Manny J. Acute superior mesenteric arterial occlusion: a plea for early diagnosis. *Surgery* 1978;83:482–5.
- 114 Bergan JJ, Dean RH, Conn J, *et al.* Revascularization in treatment of mesenteric infarction. *Ann Surg* 1975;182:430–8.
- 115 Ottinger LW. The surgical management of acute occlusion of the superior mesenteric artery. *Ann Surg* 1978;188:721–31.
- 116 Riemenschneider T, Maier G, Heitland W. Existieren Unterschiede bei Vorerkrankungen, Symptomatik, und Prognose für die verschiedenen Formen des Mesenterialinfarktes? [Are there differences in prodromal illnesses, symptoms and prognosis for various forms of mesenteric infarct?]. *Chirurg* 1987;58:823–7. German.
- 117 Edwards MS, Cherr GS, Craven TE, *et al.* Acute occlusive mesenteric ischemia: surgical management and outcomes. *Ann Vasc Surg* 2003;17:72–9.
- 118 Endean ED, Barnes SL, Kwolek CJ, *et al.* Surgical management of thrombotic acute intestinal ischemia. *Ann Surg* 2001;233:801–8.
- 119 Freeman AJ, Graham JC. Damage control surgery and angiography in cases of acute mesenteric ischaemia. *ANZ J Surg* 2005;75:308–14.
- 120 Char DJ, Cuadra SA, Hines GL, *et al.* Surgical intervention for acute intestinal ischemia: experience in a community teaching hospital. *Vasc Endovascular Surg* 2003;37:245–52.
- 121 Acosta S, Björck M. Acute thrombo-embolic occlusion of the superior mesenteric artery: a prospective study in a well defined population. *Eur J Vasc Endovasc Surg* 2003;26:179–83.
- 122 Acosta S, Wadman M, Syk I, *et al.* Epidemiology and prognostic factors in acute superior mesenteric artery occlusion. *J Gastrointest Surg* 2010;14:628–35.
- 123 Acosta S, Block T, Björnsson S, *et al.* Diagnostic pitfalls at admission in patients with acute superior mesenteric artery occlusion. *J Emerg Med* 2012;42:635–41.
- 124 Tang W, Jin B, Kuang L-Q, *et al.* Risk factors of geriatrics index of comorbidity and MDCT findings for predicting mortality in patients with acute mesenteric ischemia due to superior mesenteric artery thromboembolism. *Br J Radiol* 2020;93:20190605.
- 125 Hagmüller G, Janda A. Operationstaktik beim akuten Mesenterialarterienverschluss [Surgical tactics in acute mesenteric artery occlusion]. *Zentralbl Chir* 1988;113:1320–8. German.
- 126 Yasuhara H, Niwa H, Takenoue T, *et al.* Factors influencing mortality of acute intestinal infarction associated with SIRS. *Hepatogastroenterology* 2005;52:1474–8.
- 127 Meyer T, Klein P, Schweiger H. Wie kann die Prognose der akuten Mesenterialarterienischämie verbessert werden? Ergebnisse einer retrospektiven Analyse [How can the prognosis of acute mesenteric artery ischemia be improved? Results of a retrospective analysis]. *Zentralbl Chir* 1998;123:230–4. German.
- 128 Sifioleas MC, Moulakakis KG, Papavassiliou VG, *et al.* Acute mesenteric ischaemia, a highly lethal disease with a devastating outcome. *Vasa* 2006;35:106–11.
- 129 Ding W, Wang K, Liu B, *et al.* Open abdomen improves survival in patients with peritonitis secondary to acute superior mesenteric artery occlusion. *J Clin Gastroenterol* 2017;51:e77–82.
- 130 Dinc T, Yildiz BD, Kayilioglu I, *et al.* Red cell distribution width, gamma glutamyl transpeptidase and anticoagulant use affect mortality in acute arterial mesenteric ischemia. *Perfusion* 2015;30:337–40.
- 131 Björck M, Acosta S, Lindberg F, *et al.* Revascularization of the superior mesenteric artery after acute thromboembolic occlusion. *Br J Surg* 2002;89:923–7.
- 132 Ryer EJ, Kalra M, Oderich GS, *et al.* Revascularization for acute mesenteric ischemia. *J Vasc Surg* 2012;55:1682–9.
- 133 Arthurs ZM, Titus J, Bannazadeh M, *et al.* A comparison of endovascular revascularization with traditional therapy for the treatment of acute mesenteric ischemia. *J Vasc Surg* 2011;53:698–704.
- 134 Block TA, Acosta S, Björck M. Endovascular and open surgery for acute occlusion of the superior mesenteric artery. *J Vasc Surg* 2010;52:959–66.
- 135 Schermerhorn ML, Giles KA, Hamdan AD, *et al.* Mesenteric revascularization: management and outcomes in the United States, 1988–2006. *J Vasc Surg* 2009;50:341–8.
- 136 Zettervall SL, Lo RC, Soden PA, *et al.* Trends in treatment and mortality for mesenteric ischemia in the United States from 2000 to 2012. *Ann Vasc Surg* 2017;42:111–9.
- 137 Arya S, Kingman S, Knepper JP, *et al.* Open mesenteric interventions are equally safe as endovascular interventions and offer better midterm patency for chronic mesenteric ischemia. *Ann Vasc Surg* 2016;30:219–26.
- 138 Puippe GD, Suesstrunk J, Nocito A, *et al.* Outcome of endovascular revascularisation in patients with acute obstructive mesenteric ischaemia – a single-centre experience. *Vasa* 2015;44:363–70.
- 139 Raupach J, Lojik M, Chovanec V, *et al.* Endovascular management of acute embolic occlusion of the superior mesenteric artery: a 12-year single-centre experience. *Cardiovasc Intervent Radiol* 2016;39:195–203.
- 140 Bulut T, Oosterhof-Berkas R, Geelkerken RH, *et al.* Long-Term results of endovascular treatment of atherosclerotic stenoses or occlusions of the coeliac and superior mesenteric artery in patients with mesenteric ischaemia. *Eur J Vasc Endovasc Surg* 2017;53:583–90.
- 141 Newton WB, Sagransky MJ, Andrews JS, *et al.* Outcomes of revascularized acute mesenteric ischemia in the American College of surgeons national surgical quality improvement program database. *Am Surg* 2011;77:832–8.
- 142 Swerdlow NJ, Varkevisser RRB, Soden PA, *et al.* Thirty-Day outcomes after open revascularization for acute mesenteric ischemia from the American College of surgeons national surgical quality improvement program. *Ann Vasc Surg* 2019;61:148–55.
- 143 Zhang Z, Wang D, Li G, *et al.* Endovascular treatment for acute thromboembolic occlusion of the superior mesenteric artery and the outcome comparison between endovascular and open surgical treatments: a retrospective study. *Biomed Res Int* 2017;2017:1964765.
- 144 Andraska E, Haga L, Li X, *et al.* Retrograde open mesenteric stenting should be considered as the initial approach to acute mesenteric ischemia. *J Vasc Surg* 2020;72:1260–8.
- 145 Kärkkäinen JM, Lehtimäki TT, Saari P, *et al.* Endovascular therapy as a primary revascularization modality in acute mesenteric ischemia. *Cardiovasc Intervent Radiol* 2015;38:1119–29.
- 146 Freitas B, Bausback Y, Schuster J, *et al.* Thrombectomy devices in the treatment of acute mesenteric ischemia: initial single-center experience. *Ann Vasc Surg* 2018;51:124–31.
- 147 Branco BC, Montero-Baker MF, Aziz H, *et al.* Endovascular therapy for acute mesenteric ischemia: an NSQIP analysis. *Am Surg* 2015;81:1170–6.
- 148 Erben Y, Protack CD, Jean RA, *et al.* Endovascular interventions decrease length of hospitalization and are cost-effective in acute mesenteric ischemia. *J Vasc Surg* 2018;68:459–69.
- 149 Naazar AA, Omair A, Chu SH, *et al.* A shifting trend towards endovascular intervention in the treatment of acute mesenteric ischemia. *Cureus* 2021;13:e18544.
- 150 Andraska EA, Tran LM, Haga LM, *et al.* Contemporary management of acute and chronic mesenteric ischemia: 10-year experience from a multihospital healthcare system. *J Vasc Surg* 2022;75:1624–33.
- 151 Beyaz MO, Demir İbrahim, Ömeroğlu S, *et al.* Acute mesenteric ischemia: a disease still challenging surgeons. *Indian J Surg* 2022;84:430–5.
- 152 Girault A, Pellenc Q, Roussel A, *et al.* Midterm results after covered stenting of the superior mesenteric artery. *J Vasc Surg* 2021;74:902–9.
- 153 Chou EL, Wang LJ, McLellan RM, *et al.* Evolution in the presentation, treatment, and outcomes of patients with acute mesenteric ischemia. *Ann Vasc Surg* 2021;74:53–62.
- 154 Howard TJ, Plaskon LA, Wiebke EA, *et al.* Nonocclusive mesenteric ischemia remains a diagnostic dilemma. *Am J Surg* 1996;171:405–8.
- 155 Stockmann H, Roblick UJ, Kluge N. Diagnostik und Therapie der nicht-okklusiven mesenterialen Ischämie (NOMI) [Diagnosis and therapy of non-occlusive mesenteric ischemia (NOMI)]. *Zentralbl Chir* 2000;125:144–51.
- 156 Bryant DS, Pellicane JV, Davies RS. Nonocclusive intestinal ischemia: improved outcome with early diagnosis and therapy. *Am Surg* 1997;63:334–7.
- 157 Käser SA, Müller TC, Guggemos A, *et al.* Outcome after surgery for acute right-sided colonic ischemia without feasible vascular intervention: a single center experience of 58 patients over 6 years. *BMC Surg* 2015;15:31.
- 158 Stahl K, Busch M, Maschke SK, *et al.* A retrospective analysis of Nonocclusive mesenteric ischemia in medical and surgical ICU patients: clinical data on demography, clinical signs, and survival. *J Intensive Care Med* 2020;35:1162–72.
- 159 Takiguchi T, Nakajima M, Ohbe H, *et al.* Vasodilator therapy and mortality in Nonocclusive mesenteric ischemia: a nationwide observational study. *Crit Care Med* 2020;48:e356–61.
- 160 Singh G, Narang V, Malik AK, *et al.* Segmental enteritis: "enteritis necroticans". A clinicopathologic study. *J Clin Gastroenterol* 1996;22:6–10.
- 161 Reissfelder C, Sweiti H, Antolovic D, *et al.* Ischemic colitis: who will survive? *Surgery* 2011;149:585–92.

- 162 Endo A, Saida F, Mochida Y, *et al.* Planned versus on-demand relaparotomy strategy in initial surgery for Non-occlusive mesenteric ischemia. *J Gastrointest Surg* 2021;25:1837–46.
- 163 Rhee RY, Gloviczki P, Mendonca CT, *et al.* Mesenteric venous thrombosis: still a lethal disease in the 1990s. *J Vasc Surg* 1994;20:688–97.
- 164 Alvi AR, Khan S, Niazi SK, *et al.* Acute mesenteric venous thrombosis: improved outcome with early diagnosis and prompt anticoagulation therapy. *Int J Surg* 2009;7:210–3.
- 165 Acosta-Merida MA, Marchena-Gomez J, Hemmersbach-Miller M, *et al.* Mesenteric venous thrombosis. associated systemic disorders and hypercoagulability status of 21 surgical patients. *Hepatogastroenterology* 2007;54:1080–4.
- 166 Amitrano L, Guardascione MA, Scaglione M, *et al.* Prognostic factors in noncirrhotic patients with splanchnic vein thromboses. *Am J Gastroenterol* 2007;102:2464–70.
- 167 Acosta S, Alhadad A, Svensson P, *et al.* Epidemiology, risk and prognostic factors in mesenteric venous thrombosis. *Br J Surg* 2008;95:1245–51.
- 168 Salim S, Zarrouk M, Elf J, *et al.* Improved prognosis and low failure rate with anticoagulation as first-line therapy in mesenteric venous thrombosis. *World J Surg* 2018;42:3803–11.
- 169 Yang S-F, Liu B-C, Ding W-W, *et al.* Initial transcatheter thrombolysis for acute superior mesenteric venous thrombosis. *World J Gastroenterol* 2014;20:5483–92.
- 170 Yang S, Fan X, Ding W, *et al.* Multidisciplinary stepwise management strategy for acute superior mesenteric venous thrombosis: an intestinal stroke center experience. *Thromb Res* 2015;135:36–45.
- 171 Moschetta M, Scardapane A, Telegrafo M, *et al.* Prognostic value of tissue transition projection 3D transparent wall CT reconstructions in bowel ischemia. *Int J Surg* 2016;34:137–41.
- 172 Wadman M, Block T, Ekberg O, *et al.* Impact of MDCT with intravenous contrast on the survival in patients with acute superior mesenteric artery occlusion. *Emerg Radiol* 2010;17:171–8.
- 173 Maldonado TS, Blumberg SN, Sheth SU, *et al.* Mesenteric vein thrombosis can be safely treated with anticoagulation but is associated with significant sequelae of portal hypertension. *J Vasc Surg Venous Lymphat Disord* 2016;4:400–6.
- 174 Al-Thani H, El-Mabrok J, El-Menyar A, *et al.* Clinical presentation and outcome of mesenteric vein thrombosis: a single-center experience. *Angiology* 2015;66:249–56.
- 175 Rosendahl A, Mjörnheim B, Eriksson LC. Autopsies and quality of cause of death diagnoses. *SAGE Open Med* 2021;9:20503121211037169.
- 176 Turnbull A, Osborn M, Nicholas N. Hospital autopsy: endangered or extinct? *J Clin Pathol* 2015;68:601–4.
- 177 CDC. Stroke. Available: <https://www.cdc.gov/stroke/facts.htm> [Accessed 19 Feb 2022].
- 178 CDC. Heart disease. Available: <https://www.cdc.gov/heartdisease/facts.htm> [Accessed 19 Feb 2022].
- 179 Ferris M, Quan S, Kaplan BS, *et al.* The global incidence of appendicitis: a systematic review of population-based studies. *Ann Surg* 2017;266:237–41.
- 180 Stern E, Sugumar K, Journey JD. *Peptic ulcer perforated*. StatPearls [Internet]. Treasure Island (FL: StatPearls Publishing, 2021.
- 181 Bala M, Kashuk J, Moore EE, *et al.* Acute mesenteric ischemia: guidelines of the world Society of emergency surgery. *World J Emerg Surg* 2017;12:38.
- 182 Reintam Blaser A, Forbes A, Acosta S, *et al.* The acute mesenteric ischaemia (AMESI) study: a call to participate in an international prospective multicentre study. *Eur J Vasc Endovasc Surg* 2022;63:902–3.