Trends in population-based incidence and mortality of acute superior mesenteric artery occlusion

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Abstract

Acute occlusion of the superior mesenteric artery (SMA) results in lethal intestinal ischaemia. Results from two previous population-based studies in Malmö, Sweden, suggest a decreasing incidence of acute SMA occlusion. The study aim was to evaluate trends of the epidemiology of acute SMA occlusion in Malmö. The report was a retrospective population-based study during 2014–2019 on patients with acute SMA occlusion residing in Malmö municipality. Patients were retrieved from Skåne University Hospital and post-mortem examinations. Epidemiological data was compared to the 2000–2006 study. Seventeen patients with acute SMA occlusion resided in Malmö municipality. The incidence of acute SMA occlusion significantly decreased from 5.4/100,000 person-years to 0.8/100,000 person-years. The ratio of acute SMA occlusion to non-occlusive mesenteric ischaemia (NOMI) decreased from 12.5:1 to 0.9:1 (p < 0.0001), the proportion of inhabitants aged 80 or above in the population decreased from 6.0–4.3% (p < 0.0001), and the autopsy rates decreased from 25–14% (p < 0.0001). In-hospital mortality decreased from 63–44% (p = 0.14). The incidence of acute SMA occlusion significantly decreased in Malmö probably due to high-resolution computed tomography angiographies-around-the-clock distinguishing acute SMA occlusion from NOMI, lowered share of elderlies, improved medical risk factor control, and lowered autopsy rate.

Introduction

Acute mesenteric ischaemia (AMI) is a condition where the blood flow in the mesenteric vessels ceases, stopping the vascular supply to the intestines and causing intestinal ischaemia. If not treated adequately, this may lead to intestinal necrosis and peritonitis [1]. The most common cause of AMI is an acute thromboembolic occlusion of the superior mesenteric artery (SMA) [1–3]. Other reasons include non-occlusive mesenteric ischaemia (NOMI) and superior mesenteric vein thrombosis [1, 2]. AMI has historically been a difficult diagnosis, and clear clinical and laboratory findings for diagnosing acute SMA occlusion are still lacking [4]. Currently, the golden standard of diagnosis is computed tomography (CT) angiography: a modality with both excellent sensitivity and specificity with the advantage of being efficient and non-invasive [5–7]. The most important treatment for survival in patients with acute SMA occlusion is intestinal revascularisation, and in some cases, such as transmural bowel necrosis, additional treatment with bowel resection is indicated [1].

The population of Malmö has previously been studied regarding acute SMA occlusion in the years 1970–1982 and 2000–2006, with an incidence of 8.6 (95% confidence interval [CI] 7.6–9.7) per 100,000 person-years, decreasing to 5.4 (95% CI 4.3–6.4) per 100,000 person-years, between the decades [8, 9]. Between 2000–2006, referred to as the 2000–2006 study throughout the rest of the paper, 49 out of 100 patients underwent active intervention: 20 had intestinal revascularisation with or without bowel resection and 29 patients had bowel resection only [9]. The in-hospital mortality rate was 63%, with a cause-specific mortality rate of 3.0 per 1,000 deaths. The autopsy rate during the study period was 25%.

Recent studies have been done in other populations: a study from Helsinki, Finland between the years 2006 and 2015 found 470 individuals diagnosed with acute SMA occlusion with a total incidence rate of 3.1 per 100,000 person-years [10]. The mean autopsy rate was 29%, lower in patients aged 70 or above (18%). The study did not measure the in-hospital mortality, but instead found that the 90-day mortality rate during this period was 83%. Another study from Estonia during 2016–2020 found 347 individuals with acute SMA occlusion with an incidence rate of 5.2 per 100,000 person-years where 42% of patients underwent active intervention and the in-hospital mortality rate was 69% [3]. However, contemporaneous population-based reports on trends in incidence and mortality are missing.

The aim of this study was to evaluate trends in population-based incidence and mortality in patients with acute SMA occlusion.

Materials And Method

Reference and Study Population

Skåne University Hospital, located in both Malmö and Lund, is the sole hospital for acute and inpatient care in these cities. Vascular surgery services are however only in Malmö and is the tertiary referral hospital for 1.8 million inhabitants in the southernmost part of Sweden. The reference population was derived by calculating the average number of inhabitants in Malmö for the years 2014-2019, resulting in 331,048 inhabitants per year, with 4.3% aged 80 or above (Swedish Central Bureau of Statistics, SCB, www.statistikdatabasen.scb.se/goto/sv/ssd/DodaManadReg). During this period, the total number of deaths in Malmö was on average 2651 per year (SCB, www.statistikdatabasen.scb.se/goto/sv/ssd/BefolkningNy). The mean autopsy rate was 29%, lower in patients aged 80 or above (18%). The study did not measure the in-hospital mortality, but instead found that the 90-day mortality rate during this period was 83%. Another study from Estonia during 2016–2020 found 347 individuals with acute SMA occlusion with an incidence rate of 5.2 per 100,000 person-years where 42% of patients underwent active intervention and the in-hospital mortality rate was 69% [3]. However, contemporaneous population-based reports on trends in incidence and mortality are missing.

The aim of this study was to evaluate trends in population-based incidence and mortality in patients with acute SMA occlusion.
using the diagnostic codes 444W (embolism and thrombosis of other specified artery) and 557A (mesenteric artery) based on the Swedish version of ICD, ninth revision (ICD-9 RM). After removing duplicates, a total of 236 patients were retrieved: 194 from the search at Skåne University Hospital, 34 from the search at Department of Pathology, and eight from the search at Department of Forensic Medicine. Patient that resided outside of Malmö municipality were excluded. Other exclusion criteria when calculating epidemiological data on acute SMA occlusion were NOMI, mesenteric venous thrombosis, uncertainty if occlusive or non-occlusive mesenteric ischaemia, uncertainty if arterial or venous mesenteric ischaemia, colonic ischaemia, suspected AMI on clinical diagnosis, SMA dissection, secondary intestinal ischaemia due to intestinal obstruction, iatrogenic injuries, uncertainty if intestinal ischaemia, and not intestinal ischaemia. After applying the exclusion criteria, the total number of patients with verified acute SMA occlusion in Malmö municipality was 16 (Figure 1).

Definitions

The Distinction Between Embolus and Thrombus
The nature of native artery occlusion, embolic or thrombotic, was determined by appearance of occlusion and extent of atherosclerotic wall lesions at CT angiography [12], or angiography. Embolic occlusion appears often as an oval-shaped clot surrounded by contrast in a non-calcified arterial segment, whereas thrombotic occlusion usually appears as a clot superimposed on a heavily calcified occlusive lesion [12]. Presence of synchronous embolism, atrial fibrillation, previous embolism, and no or inadequate anticoagulation therapy in patients with atrial fibrillation at onset of AMI suggested embolism [12].

Classification of Aetiologies of AMI
The classification of aetiologies of AMI as well as nature of occlusion, thrombosis or embolism, was meticulously determined by a senior vascular surgeon (S.A.). All available CT images were carefully reviewed before determining the precise cause of AMI. On rare occasions, when CT had not been performed or was inconclusive, a combination of clinical findings, prior illnesses, surgical findings, and/or autopsy reports were used to assess the aetiology. NOMI was defined as patent SMA on CT angiography or at autopsy with concomitant severe small bowel ischaemia and/or severe colonic ischaemia restricted to the right colon. Presence of SMA stenosis may coexist in NOMI. If there was no examination of the SMA, but presence of extensive gastrointestinal ischaemia within the supply of the SMA, but not necessarily restricted to the SMA territory, with or without extraintestinal organ ischaemia, the condition was labelled as NOMI [13]. Isolated left-sided colonic ischaemia outside the primary supply of the SMA was classified as colonic ischaemia [14], and not included in the definition of NOMI or AMI [1]. No specification of localisation of ischaemia in the colon at autopsy was labelled as colonic ischaemia. Patients who died from causes other than colon infarction, but terminally developed moderate mucosal ischaemia in the colon without small bowel ischaemia found at autopsy were labelled as colonic ischaemia.

Statistics
Comparison of proportions of categorical variables between the 2000-2006 study (9) and the present study was calculated with Chi square test for \( n \geq 5 \) and Fisher’s exact test for \( n<5 \) using GraphPad QuickCalcs Web site: www.graphpad.com/quickcalcs/contingency1/ (accessed December 2022). Incidence was expressed as individuals per 100,000 person-years. Cause-specific mortality was expressed as deaths in acute SMA occlusion per 1,000 deaths in total. Confidence interval was calculated by assuming Poisson distribution and using normal distribution for \( n \geq 15 \), and exact method for smaller numbers. Significant p-value was defined as \( p<0.05 \).

Ethics
The study was approved by the Swedish Ethical Review Authority (Dnr 2022-00812-01). All research was performed in accordance with relevant guidelines and regulations. Informed patient consent was not obtained since the study was retrospective, all the data was already collected, and most patients were likely deceased when the study was conducted. Moreover, all data was presented on a group level where no individuals could be identified.

Results
Aetiologies of AMI
Of the 236 individuals retrieved between 2014 and 2019, 39 suffered from AMI in Malmö municipality: 16 (41%) were verified acute SMA occlusion, 18 (46%) were NOMI, two (5%) were either occlusive or non-occlusive mesenteric ischaemia, and three (8%) were mesenteric venous thrombosis (Figure 2). The overall incidence of AMI was 2.0 (95% CI 1.3-2.6) per 100,000 person-years.

The ratio of acute SMA occlusion to NOMI was 0.9:1, compared to 12.5:1 in the 2000-2006 study period (\( p<0.0001 \)).
Incidence of Acute Occlusion of SMA

Sixteen patients with verified acute occlusion of the SMA lived in Malmö, resulting in an incidence of 0.8 (95% CI 0.4-1.2) per 100,000 person-years (Table 1, Table 2). Seven patients were 80 years old or older. Thrombotic occlusion was found in nine and embolic in seven individuals. Incidence for women and men were 0.8 (95% CI 0.3-1.6) per 100,000 person-years and 0.8 (95% CI 0.4-1.6) per 100,000 person-years, respectively. Eleven patients underwent active intervention: seven had intestinal revascularisation only and four had both intestinal revascularisation and bowel resection.

Two patients were excluded due to uncertainty regarding the pathogenesis being of occlusive or non-occlusive nature. If assumed that they were caused by acute SMA occlusion in a sensitivity analysis, the incidence would be 0.9 (95% CI 0.5-1.3) per 100,000 person-years.

The proportion of patients aged 80 and above in the Malmö population decreased from 6.0% (2000-2006) to 4.3% (2014-2019) (p<0.0001) (Table 1).

Trends in Diagnostics and Intestinal Revascularisation Rate of Acute SMA Occlusion

The primary mode of diagnosis has shifted from surgery to CT angiography for acute SMA occlusion: 42% (n=42) were diagnosed with surgery and 27% (n=27) with CT between 2000 and 2006, whereas explorative laparotomy diagnosed 6% (n=1, p=0.0050) and CT 94% (n=15, p<0.0001) of patients between 2014 and 2019 (Table 1). Of the 15 patients diagnosed with CT, 10 underwent CT angiographies, two underwent CT with intravenous contrast in venous phase and three underwent CT without intravenous contrast. Ten (63%) patients underwent angiography with subsequent endovascular revascularisation in the latter time period (2014-2019), but no angiography was the primary mode of diagnosis. Autopsy primarily diagnosed 18% and 0%, respectively. Autopsy rates decreased from 25% to 14% (p<0.0001) and the intestinal revascularisation rate increased from 20% to 69% (p<0.0001) between the former and latter time period in Malmö.

Trends in Mortality of Acute SMA Occlusion

The in-hospital mortality rate was non-significantly reduced from 63% in 2000-2006 to 44% (p=0.14) in 2014-2019 (Table 1). Overall cause-specific death decreased from 3.0 (95% CI 2.3-3.8) per 1,000 deaths to 0.4 (95% CI 0.2-0.9) per 1,000 deaths between the two time periods.

Reports on Population-based Incidence and Mortality of Acute SMA Occlusion Including Autopsy Rates

The present population-based study was compared to other population-based reports [3, 8-10, 15] (Table 2). The highest incidence and mortality rate reported stems from Malmö in a report covering a time period from 1970 to 1982, including an autopsy rate of 87% in the population.

Discussion

The incidence of acute SMA occlusion in Malmö in the present study had a significant decrease compared to the 2000-2006 study: from 5.4 [9] to 0.8 individuals per 100,000 person-years. Even in the sensitivity analysis, the decrease in incidence to 0.9 per 100,000 person-years was significant. Several methodological and epidemiological factors likely contributed to this finding. Acute SMA occlusion was determined with greater accuracy by modern high-resolution multi-detector row CT angiography in the present study. For example, in the 2000-2006 study [9], multi-detector row CT was only performed from 2004 and onwards. In contrast to the 2000-2006 study, clinical diagnoses of acute SMA occlusion were no longer accepted as a confirmed diagnosis in the present study. This difference in inclusion contributed to a lower incidence in the present study. The high precision in classification of aetiologies of AMI resulted in a ratio of 0.9:1 between acute SMA occlusion and NOMI. In comparison, the ratio was 12.5:1 in the 2000-2006 study in Malmö [9], >15:1 in Helsinki between 2006 and 2015 [10], and 8.3:1 in Estonia between 2016 and 2020 [3]. The low percentage of NOMI in these populations may be attributed to inconclusive CTs performed with suboptimal protocols, perhaps resulting in an overestimation of patients with acute SMA occlusion.

Improved primary and secondary prevention such as lower smoking rates and better medication in cardiovascular disease may likely decrease incidence of acute SMA occlusion. In Skåne County, where Malmö is located, the smoking trend has been significantly declining from 18% in 2004-2007 to 11% in 2015-2018 [16]. A study conducted in Malmö between 2008 and 2011 analysed peripheral arterial disease in relation to treatments of its risk factors which are similar to other atherosclerotic diseases [17]. They showed that medications including acetylsalicylic acid and statins had increased when compared to 2000-2003. Novel oral anticoagulants are now widely available and have similar efficacy in preventing arterial embolism as vitamin K antagonists in atrial fibrillation [18], but are much more user-friendly. Medication with novel oral anticoagulants has been shown to have high compliance and persistence [19], and that the use of oral anticoagulation treatment has increased for post-stroke patients with atrial fibrillation since the introduction of novel oral anticoagulants [20]. Furthermore, mortality due to cardiovascular events and stroke have had a
declining trend in the last decades [21]. It is reasonable to believe that increased activity on prevention of atherosclerosis, including lower smoking rates, medical treatment, healthy diet and physical activity [22], in combination with anticoagulation treatment of atrial fibrillation, reduces the incidence of acute SMA occlusion.

Additionally, the decreasing share of inhabitants aged 80 or older and decreasing autopsy rates from 2000-2006 to 2014-2019 have likely decreased the population-based incidence rate of acute SMA occlusion.

The cause-mortality ratio decreased for acute SMA occlusion in the population of Malmö between the two time periods (2000-2006 and 2014-2019), which mainly reflected the lower incidence of the disease in the present study. Even though diagnosis made by CT improved significantly from 27% to 94%, and intestinal revascularisation rate significantly increased from 20% to 69%, it was not possible to show a significant decrease in in-hospital mortality in Malmö, even if there was an apparent large reduction in in-hospital mortality from 63% to 44%. After implementation of a pathway and care bundle for the management of acute SMA occlusion in Helsinki it was possible to show a reduction in 30-day mortality in the postintervention group (2018-2020) compared to preintervention group (2014-2017), even in the multivariable regression model among those undergoing operation [23]. Even if the data was selected and stems from operated patients only, the unique study design and results, will hopefully encourage more health care centres to follow their example.

A limitation of the study was the retrospective method with inherent risk of information bias. The study sample was limited, increasing the risk for type II statistical errors. Furthermore, the declining autopsy rate between 2000-2006 and 2014-2019, especially among the elderly [24], suggests that the incidence and mortality rates in the present study are underestimated. However, it is likely that more patients in current times are diagnosed alive with either CT angiography or explorative laparotomy in hospital than previously [9] suggesting that the role of autopsy might be of less importance. Indeed, all patients included in this study were diagnosed in-hospital. Similarly, in another contemporaneous population-based study on acute lower limb ischaemia in Malmö [11], all patients appeared to have reached the hospital in time for diagnosis, and no were diagnosed at autopsy, further strengthening this view.

A strength of the study was the thorough methodological assessment of every patient retrieved from the hospital’s patient records and port-mortem examinations. The high use of modern CT angiography resulted in reliable images for accurate diagnoses. Additionally, due to having two older population-based studies in the same demographic area, it was possible to determine trends in incidence and mortality rates, which is unique.

There is an ongoing international multicentre study, AMESI, where the incidence of different forms of AMI per hospital beds or admissions, outcome, patient characteristics, and key factors in care delay will be studied [25]. However, this study will not provide accurate epidemiological population-based incidence or mortality rates according to the prospective study protocol, particularly since it only includes patients admitted to different European hospitals, and not including ex-hospital deaths due to AMI.

Having an updated study on disease epidemiology of acute SMA occlusion in Malmö gives a unique opportunity to evaluate trend in incidence and mortality which allows the detection of possible changes of value to both caretakers and caregivers. For instance, having the means to evaluate the potential effect of preventive measures in the population. With the improved diagnostic accuracy in modern times, it is likely that the homogeneity in this study population is greater compared to previous studies, increasing the accuracy of future reports on prognostic factors, of benefit for both future patients and future research on the disease.

In conclusion, the incidence of acute SMA occlusion has drastically decreased probably due to more accurate and available high-resolution CT angiography around-the-clock distinguishing patients with acute SMA occlusion from NOMI, better medical risk factor control, lowered proportion of elderlies, and lowered autopsy rate.

Declarations

Author Contribution Statement

S.A. went through every retrieved patient and determined the proper patients to include. Y.S. then performed the data review and compiled the data base. The statistical analyses were done by Y.S. and S.A. The manuscript was mainly written by Y.S. with additions and amendments done by S.A.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, S.A., upon reasonable request.

Additional Information

The authors declare no competing interests. Correspondence and requests for materials should be addressed to S.A. (email: stefan.acosta@med.lu.se).
References


Tables

Table 1. Epidemiological characteristics of patients with acute superior mesenteric artery (SMA) occlusion in the population of Malmö. CI; Confidence interval, CT; Computed tomography. aNumber of individuals with acute SMA occlusion per 100,000 person-years. bNumber of deaths in
Acute SMA occlusion per 1,000 deaths per year.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Demographic</strong></td>
<td></td>
<td></td>
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<tr>
<td>Malmö municipality population (inhabitants)</td>
<td>267 000</td>
<td>331 048</td>
<td></td>
</tr>
<tr>
<td>Inhabitants ≥80 years (%)</td>
<td>6.0</td>
<td>4.3</td>
<td>&lt;0.0001</td>
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<tr>
<td>Autopsy frequency (%)</td>
<td>25</td>
<td>14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Overall incidence rate(^a) (n [95% CI])</td>
<td>5.4 (4.3-6.4)</td>
<td>0.8 (0.4-1.2)</td>
<td></td>
</tr>
<tr>
<td>Median age (years)</td>
<td>82</td>
<td>77</td>
<td></td>
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<tr>
<td><strong>Primary Mode of Diagnosis (n [%])</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>All</td>
<td>100</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Autopsy only</td>
<td>18 (18)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
<td>42 (42)</td>
<td>1 (6)</td>
<td>0.0050</td>
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<tr>
<td>CT</td>
<td>27 (27)</td>
<td>15 (94)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Angiography</td>
<td>2 (2)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Clinical diagnosis</td>
<td>11 (11)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Intestinal revascularisation rate (n [%])</td>
<td>20 (20)</td>
<td>11 (69)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Endovascular revascularisation (n [%])</td>
<td>14 (14)</td>
<td>10 (63)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Overall cause-specific mortality(^b) (n [95% CI])</td>
<td>3.0 (2.3-3.8)</td>
<td>0.4 (0.2-0.9)</td>
<td></td>
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<tr>
<td>In-hospital mortality (%)</td>
<td>63</td>
<td>44</td>
<td>0.14</td>
</tr>
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</table>

Table 2. Population-based incidence of acute superior mesenteric artery (SMA) occlusion including data on autopsy rate. n; number, CI; Confidence interval. \(^a\)Number of individuals with acute SMA occlusion per 100,000 person-years. \(^b\) Intestinal revascularisation and/or bowel resection. \(^c\) 90-day mortalit

<table>
<thead>
<tr>
<th>First author</th>
<th>Publication year</th>
<th>Population</th>
<th>Incidence(^a) (n [95% CI])</th>
<th>Median age (years)</th>
<th>Females (%)</th>
<th>Study period</th>
<th>Embolism: thrombosis</th>
<th>In-hospital mortality rate (%)</th>
<th>Active intervention(^b)</th>
<th>Autopsy rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acosta [15]</td>
<td>2003</td>
<td>Blekinge County, Sweden</td>
<td>5.3 (3.2-7.5)</td>
<td>84</td>
<td>67</td>
<td>1999-2002</td>
<td>5.0</td>
<td>62</td>
<td>63</td>
<td>19</td>
</tr>
<tr>
<td>Acosta [9]</td>
<td>2010</td>
<td>Malmö, Sweden</td>
<td>5.4 (4.3-6.4)</td>
<td>82</td>
<td>75</td>
<td>2000-2006</td>
<td>1.1</td>
<td>63</td>
<td>49</td>
<td>25</td>
</tr>
<tr>
<td>Lemma [10]</td>
<td>2022</td>
<td>Helsinki, Finland</td>
<td>3.1 (2.8-3.3)</td>
<td>81</td>
<td>62</td>
<td>2006-2015</td>
<td>0.8</td>
<td>83(^c)</td>
<td>38</td>
<td>29</td>
</tr>
<tr>
<td>Kase [3]</td>
<td>2022</td>
<td>Estonia</td>
<td>5.2 (4.7-5.8)</td>
<td>80</td>
<td>62</td>
<td>2016-2020</td>
<td>0.2</td>
<td>64</td>
<td>42</td>
<td>18</td>
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<tr>
<td>Soltanzadeh-Naderi</td>
<td>2023</td>
<td>Malmö, Sweden</td>
<td>0.8 (0.4-1.2)</td>
<td>77</td>
<td>50</td>
<td>2014-2019</td>
<td>0.8</td>
<td>44</td>
<td>69</td>
<td>14</td>
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**Figures**
Figure 1
Flowchart representing the identification process of the study population in Malmö municipality.

Figure 2
Aetiologies of acute mesenteric ischaemia in Malmö municipality