ORIGINAL ARTICLE

Incidence, Treatment and Mortality in Patients with Abdominal Aortic Aneurysms

An Analysis of Hospital Discharge Data from 2005–2014

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SUMMARY

Background: Aim of this study was to analyze hospital incidence, type of treatment, and hospital mortality rates of patients with abdominal aortic aneurysm (AAA) in Germany from 2005 to 2014.

Methods: Microdata of the diagnosis-related group (DRG) statistics compiled by the German Federal Statistical Office for the years 2005–2014 were analyzed. Patients who were hospitalized for a ruptured AAA (rAAA, ICD-10 code I71.3, treated either surgically or conservatively) or received surgical treatment for an unruptured AAA (nrAAA, ICD-10-Code I71.4, treated either with open surgery or an endovascular procedure) were included in the analysis. The “European Standard Population 2013” was used for direct standardization of the hospital incidences. In-hospital mortality was calculated with standardization for age and risk.

Results: The standardized overall hospital incidence of AAA was 27.9 and 3.3 cases per 100 000 people for men and women, respectively; over the period of the study, the incidence of rAAA fell by 30% in both sexes and that of nrAAA rose by 16% in men and 42% in women. The percentage of patients receiving endovascular treatment rose from 29% to 75% in patients with nrAAA and from 8% to 36% in patients with rAAA. The age- and risk-standardized in-hospital mortality of nrAAA was 3.3% in men and 5.3% in women. The in-hospital mortality of surgically treated rAAA was 39% in men and 48% in women.

Conclusion: The hospital incidence of AAA rose from 2005 to 2014, while that of rAAA fell. Endovascular treatment became more common for nrAAA as well as rAAA, and in-hospital mortality fell for both.

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Abdominal aortic aneurysms (AAA) are defined as an enlargement of the infrarenal or suprarenal aorta to a diameter of at least 3 cm, which corresponds to 1.5 times the original vessel diameter (1–3). About 3% (1–7%) of the population aged over 50 are affected by an AAA (1, 2). Risk factors include familial predisposition, smoking, and arterial hypertension, among others; in contrast, women and patients with diabetes mellitus are less frequently affected (3, 4). AAA often remain asymptomatic until rupture but then have an in-hospital mortality of about 40%. However, the total mortality of a ruptured AAA (rAAA) is presumably significantly higher due to pre-hospitalization deaths (approximately 60–80%) (1, 3, 5). The therapeutic indication for a non-ruptured AAA (nrAAA) is usually set at a diameter of 5.0–5.5 cm (for men) and 4.5–5.0 cm (for women) (3, 6). Treatment consists of open surgical repair, in which the affected vessel segment is replaced with a prosthesis (OAR, open aortic repair), or endovascular repair, by implanting a stent graft (EVAR, endovascular aortic repair) (3). An analysis of register data (>35 000 patients) of the German Vascular Society (DGG; *Deutsche Gesellschaft für Gefäßchirurgie und Gefäßmedizin*) showed a mortality rate after elective AAA therapy of approximately 3.6% for OAR and 1.3% for EVAR (7).

Although nationwide analyses in Germany on the epidemiology and treatment of AAA have already been published, they were based on nationally aggregated diagnosis-related group (DRG) data from the German Federal Statistical Office (*Statistisches Bundesamt, StBA*) (8, 9). A disadvantage of these aggregated data is that they can be evaluated either only after a hospital principal diagnosis or after treatment procedure (according to the German Classification of Operations and Procedures [*Operationen- und Prozedurenschlüssel, OPS*]). More detailed evaluations of the management and therapy of AAA in Germany were carried out using the quality assurance register of the DGG (7, 10, 11). However, this register is not legally compulsory, contains only a fraction of the AAA cases treated in Germany (<20% of the rAAA, <50% of the nrAAA), and allows neither a sex-specific nor a regional analysis (7, 10, 11).

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THE CLINICAL PERSPECTIVE

- **Typical warning signs of abdominal aortic aneurysm (AAA)**
 - AAA may manifest with chronic back or abdominal pain; however, most patients with non-ruptured AAA are asymptomatic.
 - Palpation of a pulsatile abdominal mass may be a first indication of AAA.
 - Symptomatic AAA on palpation indicates increased risk of rupture and should be followed up immediately with treatment by either open surgery or endovascular repair
 - By acute onset of strong back or abdominal pain and symptoms of hypovolaemia or hemorrhagic shock, a ruptured AAA is probable.
- **Diagnostic criteria and therapy indication**
 - An examination is performed by sonography and/or CT. In contrast to CT, MRI is not suitable for exact diagnosis and therapy planning.
 - An aneurysm is present when the transverse diameter of the abdominal aorta is enlarged by at least 1.5 times the original diameter. Thus, as a transverse diameter of 2 cm is normal, a diameter of 3 cm or more indicates an aneurysm.
 - Evaluation by a specialist in vascular surgery should occur when the aorta reaches a diameter of 4.5 cm, at the latest, and should occur earlier if asymmetric morphology or rapid growth (>3 mm per half year) is present.
 - The therapeutic indication is usually a diameter of 5.0–5.5 cm for men, and 4.5 cm for women. In addition to aneurysm size, indications include aneurysm growth, aneurysm morphology, comorbidities, life expectancy, and patient preferences.

The aim of this study was therefore to describe the hospital incidence, treatment form, and in-hospital mortality of patients with AAA from 2005 to 2014 from the patient perspective, using the DRG statistics of the StBA. In contrast to previous studies, this study describes the provision of vascular services at a national level over a long term, defines cases by linking diagnosis and procedure codes, and includes all cases treated in Germany. In addition, outcome measures were adjusted for sex and age.

Methods

Using controlled remote data processing (CRDP), the DRG statistics of the StBA were evaluated from 2005 to 2014 (e1). The basic methods of CRDP have already been described in detail (e2–e5). A detailed description of the methodology can be found in the *eBox*.

This study is a secondary data analysis based on case-related hospital discharge data (according to the Hospital Finance Act (*Krankenhausentgeltgesetz* [KHEntgG])). Microdata were stored on servers of the StBA according to the applicable data protection regulations. The total population consists of all patients who were treated in a hospital that is in compliance with § 1, KHEntgG. The geographical coverage extended over all of Germany.

The study was approved by the ethics committee of the Technical University of Munich and was carried out according to current guidelines (e6, e7).

Based on the case-specific DRG, a link was made with the G-DRG case-fee catalog of the German Institute for the Hospital Remuneration System (*Institut für das Entgeltsystem im Krankenhaus*, InEK). The sex- and age-specific population size, the type of settlement structure, the DRG case-mix, and the average length of stay were linked. Compliance with data protection regulations was ensured by employees of the Research Data Center.

Inclusion and exclusion criteria were based, in general, on the study by Landenhed (e8). In our study, all DRG cases were included for which either nrAAA (I71.4) or rAAA (I71.3) was coded as the principal or secondary diagnosis (PD, SD) during the reporting years 2005–2014. All DRG cases that had been transferred to another hospital without surgical treatment (OAR or EVAR) were excluded. The surgical treatment OPS codes 5–384.5* and 5–384.7* were used for OAR, and 5–38a.1 *, for EVAR. Details are given in *eFigure 1* and *eTable 1*.

Each analysis refers to one hospital case / episode (unit of analysis). The patient flow diagram is depicted in *eFigure 1*. We assumed that the majority of patients with nrAAA (as PD) were treated only once with OAR or EVAR, and that the majority of the patients had only a single event of a ruptured infrarenal aortic aneurysm. Thus, double counting is considered unlikely. Patients with a PD of nrAAA who were not operatively treated during the same stay (*Tables 2* and *3*) were excluded from the main analyses. This led to the following subgroups (*eFigure 1*):

- nrAAA (OP): operatively treated nrAAA
- rAAA (OP): operatively treated rAAA
- rAAA (conservative): non-operatively treated rAAA, not transferred..

The group of all patients with ruptured AAA was identified as “rAAA (all)”, and the group of all patients with either rAAA or nrAAA, as “AAA (all)”. The hospital incidence, the length of stay, the proportion of endovascularly treated patients, and the mortality in the groups of AAA (all), rAAA (all), nrAAA (OP), rAAA (OP), and rAAA (cons) were analyzed. Incidences were calculated as directly age-standardized values. The „European Standard Population 2013“ was used for direct age standardization (e9). The methods of direct and indirect age standardization have been described previously (e10). Mortality rates are reported as absolute as well as age- and risk-standardized values. The Elixhauser Comorbidity Index was used for risk standardization (e11–e13).

Statistical analysis

For metric variables, the median and the 25% and 75% quantiles were calculated. Data processing and analyses (as CRDP, using the NewVar Makro software, version 1.2, provided by the Federal Statistical Office) was carried out with the SAS statistical software, version 9.2 for Microsoft Windows (SAS Institute Inc., Cary, NC). Graphical processing of data was performed

TABLE 1

Characteristics of the patient cohort*¹

	Non-ruptured AAA	Ruptured AAA		Total
	Treated with OAR/EVAR	Treated with OAR/EVAR	Conservative measures	
Total N (%)	95 452 (81)	12 994 (11)	9 716 (8)	118 162 (100)
Men n (%) ^{*2}	83 996 (88)	10 936 (84)	7 103 (73)	102 035 (86)
Age (years, median, Q1–Q3)	72 (66–77)	75 (68–81)	79 (71–85)	73 (67–78)
Elixhauser Index (median, Q1–Q3)	5 (0–10)	8 (3–14)	5 (0–11)	5 (0–10)
As principal diagnosis (%) ^{*2}	89 244 (93)	12 330 (95)	7341 (76)	108 915 (92)
Comorbidities n (%) ^{*2}				
Coronary heart disease	33 271 (35)	3224 (25)	2087 (21)	38 582 (33)
Other ^{*3} heart disease	29 536 (31)	4987 (38)	3209 (33)	37 732 (32)
Cerebrovascular disease	7003 (7)	944 (7)	645 (7)	8592 (7)
Peripheral vascular disorders	29 736 (31)	3844 (30)	3832 (39)	37 412 (32)
Arterial hypertension	70 092 (73)	7050 (54)	4056 (42)	81 198 (69)
Chronic pulmonary disease	17 774 (19)	2082 (16)	1115 (11)	20 971 (18)
Diabetes mellitus	16 327 (17)	2027 (16)	1214 (12)	19 568 (17)
Renal Insufficiency	19 219 (20)	2959 (23)	1923 (20)	24 101 (20)
Malignant disease	3227 (3)	441 (3)	447 (5)	4115 (3)
Coagulopathy	9948 (10)	6298 (48)	1382 (14)	17 628 (15)
Obesity	11 790 (12)	1310 (10)	433 (4)	13 533 (11)

*¹ For coding, see *eTable 1*

*² Percentages refer to the total number in the first row

*³ Heart failure, arrhythmia, or aortic valve disease, among others

AAA, abdominal aortic aneurysm; EVAR, endovascular aortic repair; OAR, open aortic repair; Q, quantile

using Microsoft Excel and R (version 3.2.1; The R Foundation, www.r-project.org).

Results

Between 2005 and 2014, 118 162 patients were included in this study; 86% were men (*Table 1*). In total, 81% of patients presented with nrAAA and 19%, with rAAA. The crude hospital incidence for all AAA (nrAAA and all rAAA) was on average 13.2 per 100 000 inhabitants. The standardized hospital incidence for all AAA patients was 27.9 per 100 000 men, and 3.3 per 100 000 women. These values rose for nrAAA from 2005 to 2014 (from 20.3 to 23.6 for men, and from 2.0 to 2.8 for women, per 100 000 inhabitants) and fell for rAAA over the same period (from 6.3 to 4.4 for men, and from 1.1 to 0.8 for women, per 100 000 inhabitants). The group-specific courses of the age-standardized hospital incidence are depicted in *Figure 1* and *eFigure 2*. The median age from 2005 to 2014 was 73 years, and was higher for women than for men.

The most common documented comorbidities of AAA were arterial hypertension (69%), coronary heart disease (33%), other cardiac diseases (32%), peripheral arterial occlusive disease (32%), and renal insufficiency (20%) (*Table 1*). The coincidence of cerebrovascular

disease was 7%, and of malignant diseases, 3%. The mean Elixhauser score was 5, and the case-mix index, 4.94. Changes over time of the case-mix index and the Elixhauser score are shown in *eFigure 3*.

Patients underwent endovascular aneurysm repair (EVAR) in 48% of the overall cases, in 56% of the nrAAA cases, and in 20% of the rAAA cases (*Table 2*). The median length of stay was 11 days for nrAAA and 14 days for operatively treated rAAA. An increase in EVAR treatments, and a decrease in length of stay, are shown in *eFigures 4* and *5*. The in-hospital case volume of all AAA patients who underwent surgery or endovascular treatment was 37 per year (32 for nrAAA and 4 for rAAA).

The most common complications for all nrAAA and rAAA combined were acute limb ischemia (4.4%), acute myocardial infarction (2.0%), and acute mesenteric ischaemia (2.0%) (*eTable 3*). Mortality was 3.4% for nrAAA (with 5.3% for OAR, and 1.7% for EVAR), 40% for rAAA treated with surgery, and 71% for non-operatively treated rAAA (*Table 2*). The crude mortality of all AAA was reduced for men, from 27.4% in 2005 to 17.4% in 2014 (with a 37% relative risk reduction [RRR]) (*eFigure 6*). A similar trend was observed for women (of 14.4% to 9.7%, 33% RRR). After age and risk adjustment (*eBox*), this trend was still

FIGURE 1

Age-standardized hospital incidence from 2005–2014

* direct age standardization

AAA, abdominal aortic aneurysm; nrAAA, non-ruptured AAA; OP, operatively treated (with open surgery or endovascularly); rAAA, ruptured AAA

present but less pronounced (men, 9% RRR; women, 18% RRR) (Figure 2 and eFigure 7).

Discussion

The present study shows that, during the reporting years (2005–2014) and over all subgroups, the hospital incidence for AAA was significantly higher for men than for women. Further, the hospital incidence for nrAAA increased while that of rAAA decreased. While mortality was higher for women than for men, the overall mortality for all subgroups and for both sexes decreased.

Hospital incidence

The hospital incidence for AAA, standardized to the European Standard Population 2013, was 27.9 per 100 000 men, and 3.3 per 100 000 women. Taking into account bias due to methodological differences, these data are congruent with results from southern Sweden (of 32.6 per 100 000 men, and 5.6 per 100 000 women), among others (12). However, hospital incidence values found in analysis were at the lower end of internationally reported incidences (of 11–117 per 100 000 men, and 2.2–34 per 100 000 women) (13). It should be noted, however, that the underlying data collection procedures, the reporting periods, the health systems (and thus the remuneration system), the case definitions, and

the procedures for age standardization, including the standard populations used, were different (6, 13–18). With respect to case definitions used in this study, it was assumed that rupture of an AAA is always an indication for treatment. For nrAAA, indication for treatment was determined a posteriori (19). Thus, DRG cases would have been excluded if the patients presented with nrAAA that required treatment but were not, or could not be, treated. In the rAAA group, however, DRG cases would be included if they were coded as ruptured but for which there was no indication for treatment or therapeutic possibilities. We also cannot rule out that DRG cases are included in this group that do not actually correspond to a ruptured aortic aneurysm (but to a penetrating atherosclerotic ulcer, for instance), which required different treatments or which were encoded with an unspecified or incorrect OPS code. Indeed, such a situation could explain the relatively low mortality that we observed, of 71%, in non-treated rAAA. However, such misclassifications can not be clinically double-checked on the basis of the available data.

We observed a slightly lower hospital incidence than that reported in the literature. This may be due to the fact that our study excluded aortic aneurysms without location information (171.8/9), untreated nrAAA, thoracoabdominal aneurysms, and aneurysms due to

TABLE 2

Management and outcome^{*1}

	non-ruptured AAA	Ruptured AAA	
	Treated with OAR/EVAR	Treated with OAR/EVAR	Conservative measures
Total N (%)	95 452 (81)	12 994 (11)	9716 (8)
Type of admission n (%) ^{*2}			
Referral of physician	78 450 (82)	2200 (17)	1928 (20)
Without referral / emergency	13 788 (14)	8880 (68)	6347 (65)
Transfer from another hospital	3214 (3)	1914 (15)	1441 (15)
Diagnosis and treatment n (%) ^{*2}			
Computed tomography (CT) with contrast medium ^{*3}	39 406 (41)	7194 (55)	3038 (31)
Endovascular aortic repair (EVAR)	53 849 (56)	2559 (20)	–
Treatment at intensive care unit ^{*4}	29 548 (31)	5769 (44)	2159 (22)
Artificial respiration (yes/no)	12 105 (13)	7691 (59)	2703 (28)
Duration of ventilation (hours, median, Q1–Q3)	26 (8–117)	91 (26–347)	4 (1–64)
Length of stay, case-mix index			
Length of patient stay (days, median, Q1–Q3)	11 (8–16)	14 (5–25)	1 (1–11)
Case-mix index (median, Q1–Q3)	4.948 (3.330–5.186)	5.618 (4.434–9.746)	1.371 (0.731–2.240)
Primary outcome (%) ^{*2}			
In-hospital death	3236 (3.4)	5237 (40.3)	6926 (71.3)

^{*1} See eTable 3 for secondary outcomes and complication rates

^{*2} Percentages refer to the total number in the first row

^{*3} Only the DRG cases documented with an OPS code were recorded; therefore, externally performed CTs are not included.

^{*4} Department of Intensive Care, in accordance with Annex 2, Key 6 to the Data Transfer Agreement § 301 (3) SGB V

AAA, abdominal aortic aneurysm; DRG, diagnosis-related groups; EVAR, endovascular aortic repair; OAR, open aortic repair; OPS, German Classification of Operations and Procedures; Q, quantile

aortic dissection (I71.0) (14, 17, 19–21). In general, aortic dissection was excluded (exemplary illustration: n = 5596 cases in 2014 with dissection of the aorta as principal diagnosis; ICD-10 code I71.0), since the pathogenesis and the therapy options are significantly different. Further, although both thoracoabdominal aneurysms (n = 1667 cases in 2014, according to ICD-10 codes I71.5/6) and suprarenal aneurysms (n = 218 procedures in 2014, according to OPS code 5 384.7) have similar pathogenesis as infrarenal aneurysms, both were excluded, as they differ significantly in their treatment options, morbidity, and mortality from infrarenal aneurysms. In our opinion, this more restrictive case definition describes the patient collective more specifically, without leading to a relevant reduction in the case number.

The overall higher hospital incidence for men as compared to women (of 10:1 for nrAAA, and 6:1 for rAAA) is consistent with the results of other studies, which estimate the sex ratio to be around 2.6–6:1, although direct comparisons are difficult to make due to methodological heterogeneity (13, 22–25).

Our study found that the hospital incidence increased slightly for nrAAA, and decreased for rAAA, for both sexes; this is similar to observations from the USA (26), Sweden (27, 28) and England, Wales and Scotland (14). The course of nrAAA may reflect either

a real increase in incidence or modified DRG coding policy. In our opinion, however, it is more likely that a better awareness of disease among patients and physicians, screening programs, and improved therapeutic options have led to more patients undergoing elective treatment.

Proportion of endovascular treatments

Overall, the proportion of endovascularly treated patients increased, and more for nrAAA than for rAAA. While approximately the same percentage of men and women underwent EVAR for rAAA, women were usually less frequently treated endovascularly for nrAAA. The absolute values as well as the development over time are comparable with other countries (16, 29–31). In our opinion, the differences between the sexes for nrAAA are most likely due to distinct vascular anatomy, smaller access vessels, shorter landing zones for EVAR, and greater calcification of the vessel wall (32–34).

Hospital mortality

Standardized in-hospital mortality decreased slightly, similar to other countries (26, 31), but was lower for men than for women in all subgroups and over all years. The hospital mortality for nrAAA, of an average of 3.3% for men and 5.3% for women, is comparable

FIGURE 2

Mortality (age- and risk-adjusted) for the period from 2005 to 2014 (for raw values, see eFigure 6)

* The Elixhauser Index was used for risk adjustment (40).

AAA, abdominal aortic aneurysm; nrAAA, non-ruptured AAA; OP, operatively treated (with open surgery or endovascularly); rAAA, ruptured AAA

with other countries (including the United States, Great Britain, Switzerland, Sweden, and Australia; men, 2.1–3.6%, women 2.9–6.5% [31, 35]). Sex-specific differences are probably due to anatomical characteristics, lifestyle factors, sex hormones, immunological processes, or genetic causes (13). It is also assumed that cardiovascular diseases are more often underdiagnosed in women (36). For rAAA, the overall sex-specific difference of in-hospital mortality is lower than for nrAAA; the absolute values for men (39%) and women (48%) are also comparable with those from other countries (men, 28–44%, and women, 22–53% [31, 35]). Variability between study results is most likely due to different standardization procedures for age and risk, distinct reporting periods, and varying proportions of endovascularly treated patients, making a comparison difficult. Interestingly, as shown in eFigure 3, women presenting with nrAAA generally have a higher Elixhauser risk score but the same case-mix index, whereas the opposite is observed for women presenting with rAAA (i.e., lower case-mix index with the same risk score). Despite possible coding effects, the higher risk score for women with nrAAA could indicate a higher comorbidity, which—in combination with the generally higher age and lower percentage of EVAR in women (eFigure 4)—explains the increased hospital mortality.

This is a likely reason for prolonged in-hospital stays of female patients presenting with nrAAA. Additionally, women often live longer than their husbands, which could lead to a longer length of hospital stay in the absence of support from the spouse and if home care is lacking (37, 38). As the diameters of aneurysms are not recorded in the DRG data, we can only speculate as to whether women, who have constitutionally smaller vessels, only reach an aneurysm size of 5.0–5.5 cm at an advanced age, and thereby with the indication of treatment being „too late“. In addition, women already have a higher risk of rupture at smaller AAA diameters (39).

Limitations

There are several limitations to this analysis, which are briefly summarized here (and given in more detail in the eBox):

- Data are not clinical, but administrative, so that miscoding or changes in coding procedures could lead to biased case selection, case grouping, diagnoses, and procedures.
- While overreporting is rather unlikely due to regular monitoring by the Health Insurance Medical Service (*Medizinischer Dienst der Krankenversicherungen*; MDK), an underreporting

of secondary diagnoses or procedures that are not relevant to DRGs may be assumed.

- Risk-adjustment of mortality included only age, sex, and Elixhauser score. While the latter is a validated instrument (40), some aneurysm-specific risk factors, such as diameter of aneurysm and technical level of expertise, are not available in the database.
- The observation period ended with the patient's discharge from the hospital. Deaths and complications that occurred after hospital discharge were not recorded.
- Secondary („soft“) outcomes, such as quality of life or other „patient-reported outcomes,“ were not recorded and therefore could not be analyzed.

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Conflict of interest statement

The authors declare that no conflict of interest exists.

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KEY MESSAGES

- Between 2005 and 2014, the hospital incidence increased for non-ruptured abdominal aortic aneurysms (nrAAA) and decreased for ruptured abdominal aortic aneurysms (rAAA).
- Overall, the hospital incidence was higher (by up to ten times) for men than for women.
- Both the average patient age and the comorbidity (measured by the case-mix index and Elixhauser Index) increased slightly.
- The proportion of endovascularly treated patients increased significantly for nrAAA and rAAA, accompanied by a shortened length of hospital stay (especially for nrAAA).
- In-hospital mortality was in general higher for women than for men, but it decreased overall for both sexes and for both nrAAA and rAAA.

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Supplementary material

For eReferences please refer to:
www.aerzteblatt-international.de/ref2217

eBox, eFigures, eTables:
www.aerzteblatt-international.de/17m0391

CLINICAL SNAPSHOT

Pulmonary perfusion scintigraphy with the radiopharmaceutical Tc-99m-MAA as an outpatient study

Acute Pulmonary Embolism

An 87-year-old man presented in poor overall condition because of progressively severe dyspnea of 10 days' duration. He underwent pulmonary perfusion scintigraphy. The image shows a nearly total absence of perfusion of the right upper lobe and of multiple other regions in both lungs. In particular, the clearly circumscribed perfusion deficit on the right was pathognomonic for pulmonary embolism. Accordingly, the lung perfusion fractions were abnormally asymmetric—67% on the left and 33% on the right. Low-molecular-weight heparin was given and the patient was urgently admitted to the hospital. A further study revealed a four-level deep venous thrombosis of the left lower limb as the source of the massive pulmonary arterial embolus. This case illustrates the key role of scintigraphy in the sequence of diagnostic tests for pulmonary embolism. Despite the severity of this patient's problem, a rapid and sensitive diagnostic study enabled the immediate initiation of appropriate treatment, with a successful outcome.

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Conflict of interest statement

The authors declare that no conflict of interest exists.

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Supplementary material to:

Incidence, Treatment and Mortality in Patients with Abdominal Aortic Aneurysms

An Analysis of Hospital Discharge Data from 2005–2014

by Andreas Kühnl, Alexander Erk, Matthias Trenner, Michael Salvermoser, Volker Schmid, and Hans-Henning Eckstein

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eMethods

Using controlled remote data processing (CRDP), the DRG statistics of the German Federal Statistical Office (StBA) were evaluated from 2005 to 2014 (e1). The basic methods for CRDP of DRG statistics have been previously used and described in detail in other studies (e2–e5).

This study is a secondary data analysis. A study protocol was submitted to the StBA as part of the application procedure (but has not been separately published).

The present analysis is a complete survey based on case-related data of hospitals submitted to the StBA between 2005 and 2014 by the German Institute for the Hospital Remuneration System (InEK) according to § 21 Hospital Finance Act (Krankenhausentgeltgesetz [KHEntgG]). The survey population comprised all patients who were admitted to and treated in a hospital that is reimbursed according to the DRG remuneration system and is subject to §1 KHEntgG (in principle, this includes all German hospitals without psychiatric facilities, with a few exceptions). The geographical coverage extended over all of Germany.

The legal basis for the scientific use of the DRG statistics of the StBA for secondary data analyses is given in Article 3a Paragraph 2 and Article 16 Paragraph 6 of the German Federal Statistics Act [Bundesstatistikgesetz]. The study was approved by the ethics committee of the Technical University of Munich and was carried out according to the guidelines for good practice of secondary data analysis (e6). This publication was based on the standardized reporting guidelines of secondary data analysis, STROSA2 (e7).

Microdata are stored on StBA servers according to the applicable data protection regulations. Data access by the workgroup took place exclusively via CRDP.

Based on the Official Municipality Key, the StBA and the Federal Institute for Research on Building, Urban Affairs, and Spatial Development (BBSR; INKAR online database) were linked. Based on case-specific DRGs, links were made with the G-DRG case-fee catalog of InEK. The sex- and age-specific population, type of settlement structure (e.g., larger city, urban region, or densely or sparsely populated rural region), DRG case-mix, and the average length of stay were linked. Compliance with data protection regulations was ensured by employees of the Research Data Center.

The inclusion and exclusion criteria were based on the study by Landenhed (e8). In our study, all DRG cases were included for which a non-ruptured abdominal aortic aneurysm (nrAAA) (I71.4) or a ruptured abdominal aortic aneurysm (rAAA) (I71.3) was used as the principal or secondary diagnoses (PD, SD) in the 2005–2014 reporting period. All DRG cases that were transferred to another hospital without operative treatment during the same stay (OAR or EVAR) were excluded. The OPS codes 5–384.5 * and 5–384.7 * for OAR, and 5–38a.1 * for EVAR, were used for surgical repair. Details can be found in *eFigure 1* and *eTable 1*.

All analyses refer to one hospital case (unit of analysis). A linkage to individual patients could not be made with the data. The patient flow diagram is depicted in the *eFigure 1*. In order to identify the treating hospital, the institution identification (IK) and the “discharge location,” homogenized over the years 2005–2014, were used. Homogenization was carried out by the Federal Statistical Office and was based on the institute identification (IK), hospital name, and street address. It was assumed that the majority of patients presenting with nrAAA (as a PD) were treated only once with OAR or EVAR, and that the majority of the patients only had one incident of rAAA; thus, double counts would be rare. However, a not insignificant portion of patients who had a hospital PD of nrAAA were admitted for diagnosis or completion therapy (e.g., for endoleak treatment) in-hospital. Therefore, to avoid double counting in these cases, patients with a PD of nrAAA who were not operatively treated during the same stay (*eTables 2 and 3*) were excluded from the main analyses. Thus, the following subgroups were considered (*eFigure 1*):

- nrAAA (OP): operatively treated nrAAA
- rAAA (OP): operatively treated rAAA
- rAAA (cons): non-operatively treated rAAA, not transferred.

The group of all patients with ruptured AAA was identified as “rAAA (all)”, and the group of all patients with either rAAA or nrAAA, as “AAA (all)”. Variable names and codes were taken from the dataset description of the StBA. The hospital incidence, the length of stay, the proportion of endovascularly treated patients, and the mortality in the groups of AAA (all), rAAA (all), nrAAA (OP), rAAA (OP), and rAAA (cons) were analyzed. Incidences were calculated as raw values (data not shown) as well as directly age-standardized values. The “European Standard Population 2013” was used for direct age standardization (e9), which, in contrast to the actual age distribution in Germany, gives slightly more weight to the younger age groups, and slightly less to the older age groups. Standardization to a publicly available standard distribution serves primarily to allow comparisons with future (international) studies. The methods of direct and indirect age standardization have been described previously (e10). Mortality was reported as an absolute value as well as values indirectly adjusted to age and risk. Risk standardization used the Elixhauser Comorbidity Index (e11–e13).

Statistical analysis

As the survey covers the reporting years from 2005 to 2014, confidence intervals (CI) need not be calculated for each reporting year; however, analyzing the distribution over the entire analysis period 2005–2014 provides an impression of the variance expected in the future. The median and the 25% and 75% quantiles were therefore calculated for metric variables. A post-hoc power calculation was also not necessary (e14). Data processing and analysis (as controlled remote data processing [CRDP]) were carried out using the statistical program SAS, version 9.2 for Microsoft Windows (Copyright © 2015 SAS Institute Inc., Cary, NC, USA). Graphical preparation of the data was done with Microsoft Excel as well as with the R statistics program (version 3.2.1, The R Foundation, www.r-project.org).

DRG, diagnosis-related groups; OAR, open aneurysm repair; OPS, German Classification of Operations and Procedures; EVAR, endovascular aneurysm repair

eFIGURE 1

Patient flow diagram

* operative treatment of aneurysm by open surgery, endovascular aortic repair, or combination surgery. The characteristics of the excluded subgroups can be found in eTable 2.

AAA, abdominal aortic aneurysm; DRG, diagnosis-related groups; nrAAA, non-ruptured AAA; ICD, International Classification of Diseases; PD, principal diagnosis; rAAA, ruptured AAA; SD, secondary diagnosis

eFIGURE 2

Age-standardized hospital incidence for all included AAA (left) and all included rAAA (right) from 2005–2014

* directly age-standardized

AAA, abdominal aortic aneurysm; rAAA, ruptured AAA

eFIGURE 3

Time period 2005–2014 for the median case-mix index (top) and the median Elixhauser Comorbidity Index (bottom) for treated nrAAA (left) and rAAA (right)

AAA, abdominal aortic aneurysm; nrAAA, non-ruptured AAA; OP, operatively treated (with open surgery or endovascularly); rAAA, ruptured AAA

eFIGURE 4

Proportion of endovascularly-treated patients presenting with nrAAA (left) or rAAA (right) during 2005–2014

AAA, abdominal aortic aneurysm; EVAR, endovascular aneurysm repair; nrAAA, non-ruptured AAA; OP, operatively treated (with open surgery or endovascularly); rAAA, ruptured AAA

eFIGURE 5

Median length of stay for patients treated for nrAAA (left) or rAAA (right) during 2005–2014

AAA, abdominal aortic aneurysm; nrAAA, non-ruptured AAA; OP, operatively treated (with open surgery or endovascularly); rAAA, ruptured AAA

eFIGURE 6

Raw values for in-hospital mortality

AAA, abdominal aortic aneurysm; nrAAA, non-ruptured AAA; OP, operatively treated (with open surgery or endovascularly); rAAA, ruptured AAA

eFIGURE 7

Mortality (age- and risk-adjusted) for all included AAA (left) as well as for all included rAAA (right) from 2005–2014 (for raw values, see eFigure 6).

*The Elixhauser Index was used for risk adjustment (40).

AAA, abdominal aortic aneurysm; rAAA, ruptured AAA

eTABLE 1

Codes used based on OPS or ICD-10, according to the available version from DIMDI (www.dimdi.de)

Description	Source	Codes, references
rAAA	ICD-10	I71.3
nrAAA	ICD-10	I71.4
OAR	OPS	5–384.5, 5–384.7
EVAR	OPS	5–38a.1
For characteristics and comorbidities (Table 1, eTable 2)		
Elixhauser Index (EI)	Literature	van Walraven et al. (e12), Quan et al. (e15, e16)
Charlson Comorbidity Index (CCI)	Literature	Quan et al. (e15, e16)
Coronary heart disease	ICD-10	I25*
Other heart diseases	EI (e13)	Elixhauser item Nr. 1–3
Cerebrovascular diseases	CCI (e15)	CCI item Nr. 4
Peripheral vascular disorders	EI (e13)	Elixhauser item Nr. 5
Arterial hypertension	EI (e13)	Elixhauser item Nr. 6
Chronic pulmonary disease	EI (e13)	Elixhauser item Nr. 9
Diabetes mellitus	EI (e13)	Elixhauser item Nr. 10, 11
Renal insufficiency	EI (e13)	Elixhauser item Nr. 13
Malignant diseases	EI (e13)	Elixhauser item Nr. 17–19
Coagulopathy	EI (e13)	Elixhauser item Nr. 21
Obesity	EI (e13)	Elixhauser item Nr. 22
For diagnostics and management (Table 2, eTable 2)		
Diagnostic procedures	OPS	1*
Imaging diagnostics	OPS	3*
–Computed tomography (all)	OPS	3–206, 3–207, 3–225, 3–226
–Computed tomography (with CM)	OPS	3–225, 3–226
Operative measures	OPS	5*
Non-operative measures	OPS	8*
ICU stay	–	Department: 3600, 3690, 3691, 3692, 3693, 3694, 3695, 3696, 3697, 3698, 3699, 0436, 1536, 2036, 2050, 2136, 2150, 3601, 3603, 3617, 3618, 3621, 3650, 3651, 3652
For complications and secondary outcomes (eTable 3)		
Acute myocardial infarction	ICD-10	I21.*, I22.*
Resuscitation	OPS	8–77*
Acute limb ischaemia	ICD-10	I74.*
Major amputations	OPS	5–864.*
Acute mesenteric ischemia	ICD-10	K55.0
Bowel resection	OPS	5–45*
Acute renal ischemia	ICD-10	N28.0
Hemodialysis, hemofiltration	OPS	8–853, 8–854, 8–855, 8–857
Transfusion >6 RBC	OPS	8–800.7* without 8–800.7f 8–800.c* without 8–800.c0
Transfusion >6 PC	OPS	8–800.6* without 8–800.60/.61/.62/.63 8–800.8* without 8–800.8s 8–800.a* without 8–800.a0 8–800.b* without 8–800.b0/.b1/.b2/.b3 8–800.e* without 8–800.e0/.e1/.e2/.e3 8–800.9* without 8–800.9v/.90/.91/.92/.93 8–800.d* without 8–800.d0/.d1/.d2/.d3/.d4

AAA, abdominal aortic aneurysm; CCI, Charlson Comorbidity Index; CM, contrast medium; DIMDI, German Institute of Medical Documentation and Information; EI, Elixhauser Index; EVAR, endovascular aneurysm repair; ICD, International Classification of Diseases; ICU, intensive care unit; nrAAA, non-ruptured AAA; OAR, open aortic repair; OPS, German Classification of Operations and Procedures; PC, platelet concentrates; rAAA, ruptured AAA; RBC, red blood cell concentrates

eTABLE 2

Characteristics of excluded patients with I71.4 as a principal or secondary diagnosis but without an operative treatment (without OAR or EVAR during the stay)

	non-ruptured AAA, non-operatively treated	
	As principal diagnosis	As secondary diagnosis
Total N (%)	35 868 (100)	285 464 (100)
Men n (%)	30 024 (84)	222 290 (78)
Age (years, median, Q1–Q3)	74 (68–80)	76 (70–82)
Elixhauser Index (median, Q1–Q3)	5 (0–9)	9 (2–15)
Comorbidities, n (%)		
Coronary heart disease	12 893 (36)	113 919 (40)
Cerebrovascular disease	2 918 (8)	37 712 (13)
Arterial hypertension	24 185 (67)	187 196 (66)
Chronic pulmonary disease	5 787 (16)	54 413 (19)
Renal insufficiency	10 511 (29)	83 343 (29)
Coagulopathy	1 397 (4)	14 864 (5)
Obesity	3 373 (9)	19 751 (7)
Type of settlement of patient residence, n (%)		
Independent (district-free) large city	11 124 (31)	90 839 (32)
Urban district	12 716 (35)	109 926 (39)
Rural district	5 824 (16)	43 577 (15)
Sparsely populated rural district	6 204 (17)	41 122 (14)
Type of settlement of hospital, n (%)		
Independent large city	19 576 (55)	127 758 (45)
Urban district	8 307 (23)	88 770 (31)
Rural district	4 230 (12)	35 398 (12)
Sparsely populated rural district	3 755 (10)	33 538 (12)
Type of admission, n (%)		
Referral of physician	27 108 (76)	151 269 (53)
Without referral / emergency	6 290 (18)	117 951 (41)
Transfer	2 463 (7)	16 214 (6)
Unknown	7 (0)	30 (0)
Procedures, n (%)		
– Diagnostic procedures	8 703 (24)	117 086 (41)
– Imaging diagnostics	27 164 (76)	143 939 (50)
Computed tomography (CT) total	16 406 (46)	67 263 (24)
Computed tomography with CM	14 930 (42)	57 884 (20)
– Operative measures	6 208 (17)	89 650 (31)
– Non-operative measures	12 278 (34)	143 416 (50)
Resuscitation (OPS 8–77)	372 (1.0)	3 107 (1.1)
Intensive therapy	2 533 (7.1)	21 274 (7.5)
Respiratory assistance (yes/no)	1 505 (4.2)	13 102 (4.6)
Hemodialysis, hemofiltration	792 (2.2)	7 532 (2.6)

	non-ruptured AAA, non-operatively treated	
	As principal diagnosis	As secondary diagnosis
Length of stay/DRG (median, Q1–Q3)		
Length of patient stay (days, median, Q1–Q3)	3 (2–8)	8 (4–14)
mLOS (days, median, Q1–Q3)	7 (6–7)	8 (5–12)
Case-mix index (median, Q1–Q3)	0.737 (0.699–1.441)	0.942 (0.679–1.613)
Outcome, n (%)		
In-hospital mortality	1160 (3.2)	16 543 (5.8)
Type of discharge for survivors, n (%)		
Treatment ended normally	33 045 (92.1)	247 337 (86.6)
Discharge against medical advice	596 (1.7)	3057 (1.1)
Transfer to rehabilitation	545 (1.5)	9629 (3.4)
Transfer to another hospital	–	–
Other types of discharge*	522 (1.5)	8898 (3.1)

* This includes transfer to other locations (such as hospices and psychiatric wards) and discharge for administrative reasons (for example, due to change of insurance provider or of the remuneration system).
AAA, abdominal aortic aneurysm; DRG, diagnosis-related groups; EVAR, endovascular aortic repair; CM, contrast medium; mLOS, year-specific mean of length of stay of the billed DRG; OAR, open aortic repair; OPS, German Classification of Operations and Procedures; Q, quantile

eTABLE 3

Complications and secondary outcomes

	non-ruptured AAA	Ruptured AAA	
	Treated with OAR/EVAR	Treated with OAR/EVAR	Conservative measures
Total N (%)	95 452 (81)	12 994 (11)	9716 (8)
Complications/procedure n (%) ^{*1}			
Acute myocardial infarction (ICD-10: I21, I22)	1566 (1.6)	620 (4.8)	235 (2.4)
Resuscitation (OPS: 8–77)	1495 (1.6)	1549 (11.9)	2183 (22.5)
Acute limb ischaemia (ICD-10: I74)	3863 (4.0)	1067 (8.2)	213 (2.2)
Major amputation (OPS: 5–864)	237 (0.2)	158 (1.2)	29 (0.3)
Acute mesenteric ischemia (ICD-10: K55.0)	1135 (1.2)	1061 (8.2)	212 (2.2)
Bowel resection (OPS: 5–45)	1377 (1.4)	1006 (7.7)	232 (2.4)
Acute renal ischemia (ICD-10: N28.0)	550 (0.6)	122 (0.9)	44 (0.5)
Hemodialysis, hemofiltration	3183 (3.3)	2728 (21.0)	576 (5.9)
Transfusion >6 RBC	6744 (7.1)	8108 (62.4)	1706 (17.6)
Transfusion >6 PC	442 (0.5)	851 (6.5)	139 (1.4)
Length of stay/DRG (median, Q1–Q3)			
Difference ^{*2}	–2 (–4 to 2)	–6 (–16 to 2)	–5 (–10 to –2)
Type of discharge for survivors n (%) ^{*1}			
Treatment ended normally	84 804 (92.0)	5238 (67.5)	2 222 (79.6)
Discharge against medical advice	420 (0.5)	34 (0.4)	53 (1.9)
Transfer to rehabilitation	3615 (3.9)	1125 (14.5)	356 (12.8)
Transfer to another hospital	2730 (3.0)	1196 (15.4)	–
Other types of discharge ^{*3}	647 (0.7)	164 (2.1)	159 (5.7)

^{*1} Percentages refer to the total number in the first row

^{*2} “actual length of patient stay” minus “average length of stay of the DRG to which the corresponding case belongs”

^{*3} This includes transfer to other locations (such as hospices and psychiatric wards) and discharge for administrative reasons (for example, due to change of insurance provider or of the remuneration system)

AAA, abdominal aortic aneurysm; DRG, diagnosis-related groups; EVAR, endovascular aortic repair; ICD, International Classification of Diseases; mLOS, year-specific mean of length of stay of the billed DRG; OAR, open aortic repair; OPS, German Classification of Operations and Procedures; PC, platelet concentrates; Q, quantile; RBC, red blood cell concentrates