World J Surg (2019) 43:2320–2327
https://doi.org/10.1007/s00268-019-05023-w

ORIGINAL SCIENTIFIC REPORT

# A Population-Based Study of Incidence, Presentation, Management and Outcome of Primary Thromboembolic Ischemia in the Upper Extremity

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Published online: 13 May 2019


## Abstract

*Objectives* To investigate the epidemiology of acute upper limb thromboembolism in a well-defined Norwegian population.

*Methods* This study was a retrospective, single-center, observational population-based cohort study of acute upper limb thromboembolism. The study included all patients from the hospital's primary catchment area from January 2000 to December 2015. Age- and gender-adjusted incidence rates were calculated using population demographics from Statistics Norway.

*Results* A total of 54 patients were identified, of which 49 were included in the analyses: 27 (55%) females (median age 83 years, range 40–96) and 22 (45%) males (median age 70 years, range 42–95) ($P$ = .053). The adjusted incidence rate for the period was 1.6 patients per 100,000 inhabitants per year (95% confidence interval 1.2–2.2) and did not change significantly during the period studied. Atrial fibrillation was detected by electrocardiography in 30 (61%) patients; in this group, 10 patients were on warfarin but only two had an international normalized ratio > 1.9 and the remaining 20 were not anticoagulated. Altogether, 38 (78%) patients underwent surgery, 1 (2%) was treated with thrombolysis, and the remaining patients were treated conservatively; no amputations were performed. Four patients (8%) died within 30 days, and 12 of the surviving 45 patients (27%) had recurrent thromboembolism.

*Conclusion* The incidence rate was stable during the study period. Patients with upper limb thromboembolism due to atrial fibrillation were inadequately anticoagulated. One in four patients experienced a recurrent thromboembolic event. Lifelong anticoagulation should be considered in all patients with upper limb thromboembolism.

## Introduction

Acute upper limb thromboembolism is a rare entity with an incidence of approximately 20% that of lower limb ischemia [1]. Nevertheless, it is a vascular emergency with a potential devastating effect on life and limb. The serious aspect is partly explained by its strong association with atrial fibrillation (AF) as patients with AF face an increased risk of ischemic stroke and death [2]. Anticoagulation therapy is known to significantly reduce the risk of subsequent thromboembolism, stroke and death in AF [3].

The diagnosis of acute upper limb thromboembolism is usually straightforward on presentation, and the degree of ischemia depends above all on the level of occlusion, but

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also on the existing collateral network. Acute upper limb thromboembolism has generally been reported to have lower mortality and amputation rates than acute ischemic events in the lower extremities [1, 4]. Most of the available studies are case series and not population based [1, 4, 5]. Thus, the generalizability may be questionable. The guidelines of the European Society of Vascular and Endovascular Society and the US Society of Vascular Surgery do not give any recommendations on how to treat thromboembolism in the upper extremity [6, 7].

In order to get a reliable estimate of the nature and scope of a disease, population-based studies are needed. Few population-based studies on acute upper limb thromboembolism have been published the last 40 years, and the ones at hand are registry based, limited to patients undergoing surgery or from the era before AF was routinely treated by anticoagulation [8–10]. Furthermore, the reported incidence rates are not consistent and vary widely. One may speculate that acute upper limb thromboembolism is on the increase as the population is aging and age is one of the major determinants of AF [11]. The aim of this study was to examine the epidemiology and outcome of thromboembolism in the upper extremity in a well-defined population.

## Methods

The study was approved by the Regional Committee for Medical and Health Research Ethics (REK 2015/2326). All living patients received written information on the study and were given the opportunity to make a reservation against registration of personal information. The study was, to the best of our ability, conducted according to the STROBE guideline for observational research [12].

### Study design and population

In this retrospective population-based, consecutive cohort study, we included all cases of acute upper limb thromboembolism from January 2000 to December 2015. The patients were identified by searching the operation database and the electronic patient journal system for a variety of International Classification of Diseases (ICD) codes (I74.2, I74.4, I74.8, I74.9, I72.1, S45.0, S45.1, S45.2) in order not to miss incorrectly coded cases. Stavanger University Hospital (SUH) is the only hospital in the southern part of Rogaland County and covers the mixed urban area of Stavanger and the greater surrounding rural area. The area has low emigration, and year-by-year population statistics (Statistics Norway, www.ssb.no) make the population ideal for epidemiological studies [13, 14]. During the study period, the catchment population increased from 282,000 in 2000 to 360,000 in 2015. SUH receives referrals from a larger area for a population of up to 500,000.

### Definitions, inclusion and exclusion criteria

Patients older than 20 years with primary thromboembolic ischemia affecting the upper extremity were included in the study, whereas chronic ischemia (duration $> 2$ weeks) secondary to, e.g., atherosclerosis, thromboangiitis obliterans or connective tissue disease was excluded. Acute ischemia secondary to trauma, self-harm or occlusion of prior surgical construction (e.g., bypass) was also excluded. Considering the epidemiological, population-based design of the study, patients from outside SUH's primary catchment area were not included. The diagnosis of acute upper limb thromboembolism was based on finding an embolus on computer tomography angiography, conventional angiography, ultrasound or operation. In a few cases, the diagnosis was based on clinical findings only.

All patients had an electrocardiogram (ECG) on admission, and the $CHA_2DS_2VASc$ score was calculated for all patients with AF. The $CHA_2DS_2VASc$ score [15] calculates the risk of stroke, and the recommendation is that anticoagulation should be considered in patients with a score of one or higher. The score is based on risk factors (congestive heart failure, hypertension, age $> 75$ years, diabetes mellitus, stroke/TIA/thromboembolism, vascular disease and gender).

### Statistical analysis

The analyses were performed with the Statistical Package for Social Sciences (SPSS v24; IBM, Armonk, NY) and R v3.4.3 [16]. The R-package "relsurv" version 2.0-9 was used for relative survival calculations [17] and the R-package "epitools" for adjusted incidence calculations [18].

The Chi-square test or Fisher exact test was used as appropriate to test for differences in categorical variables between groups. The Mann–Whitney test was used to test for differences between groups in continuous variables. Age- and gender-adjusted incidence rates were calculated by direct standardization with 10-year intervals for age, using the Norwegian population as references. Survival curves were estimated by the Kaplan–Meier estimator, and the log-rank test was used to test for differences in survival distribution between groups. Relative survival curves, estimating the ratio of survival in the patient group versus the overall survival in a normal population with the same age, gender and birth year distribution as the patient groups, were also calculated [17]. For relative survival and incidence calculations population data were obtained from Statistics Norway.

All statistical tests were two-sided, and $P$ values $< .050$ were regarded as statistically significant.

## Results

### Patient characteristics

A total of 54 patients with acute upper limb thromboembolism were identified in the 16-year study period. Two patients, one man and one woman, had reservations against participation in the study. These two persons have been included in the incidence and mortality analyses as the information could be gathered without accessing their personal data in the electronic patient journal, but data pertaining to the two persons have not been included in the other results (tables and text). A further three patients were excluded as they were from outside SUH's primary catchment area. Thus, 49 patients were available for analysis, comprising 27 (55%) females and 22 (45%) males. Women included in the study were older than the men, but not significantly ($P = .053$).

On admission, AF was detected on ECG in 30 (61%) patients. The characteristics of patients with or without AF are given in Table 1. AF had previously been diagnosed in 25 of these patients, but only 10 patients were under treatment with warfarin and only two patients had an international normalized ratio (INR) > 1.9. The $CHA_2DS_2VASc$ score prior to the thromboembolic event for the 30 patients with AF on admission was calculated and only one patient had a score of 0 and the remaining had a score of one or higher (Table 2). Two patients without AF were on direct oral anticoagulants (DOAC) on admission. Four patients developed AF at a later date (> 30 days).

### Assessment and treatment

All the patients had symptoms of upper limb ischemia, and 38 of 49 patients (78%) were admitted within 24 h from symptom debut. Contrast-enhanced CT was performed in 27 patients (55%), conventional angiography in 3 (6%) and duplex ultrasound in 3 (6%). In the remaining 16 (33%) the diagnosis was made by clinical assessment and confirmed on operation in 12. The affected side and level of occlusion are shown in Fig. 1.

A concomitant thromboembolic event at a different anatomic location was registered in 8 of 49 patients (16%) on admission: cerebral (five patients), cardiac (one patient), lower limb (one patient) and renal (one patient). All patients with concomitant thromboembolism had AF.

Thromboembolectomy was performed in 38 patients (78%); one (2%) was successfully treated with intra-arterial thrombolysis. Eight of the patients (16%) had mild symptoms and the extremity was perceived as not threatened and they were treated with systemic anticoagulation and observation alone. None of the patients that were treated conservatively were later in need of surgery. Two patients (4%) were moribund on admission due to serious

**Table 1** Patient characteristics at time of admission

| | Atrial fibrillation | Sinus rhythm | $P$ |
|---|---|---|---|
| Number of subjects | 30 (61%) | 19 (39%) | |
| Median age | 83 (range 57–96) | 65 (range 40–91) | .002 |
| *Gender* | | | |
| Male | 12 (40%) | 10 (53%) | .386 |
| Female | 18 (60%) | 9 (47%) | |
| *History of* | | | |
| Ischemic heart disease | 10 (33%) | 7 (37%) | .801 |
| Other arrhythmias | 1 (3%) | 1 (5%) | 1.0 |
| Congestive heart failure | 5 (17%) | 1 (5%) | .384 |
| Pacemaker/ICD | 2 (7%) | 2 (11%) | .636 |
| Hypertension | 18 (60%) | 4 (21%) | .009 |
| Renal failure | 2 (7%) | 1 (5%) | 1.0 |
| Cerebrovascular disease | 11 (37%) | 3 (16%) | .194 |
| Diabetes | 3 (10%) | 0 (0%) | .273 |
| Previous episode of acute arterial thromboembolism | 9 (30%) | 4 (21%) | .741 |
| Prevalent cancer disease | 2 (7%) | 2 (11%) | .636 |
| Symptomatic lower extremity arterial disease | 1 (3%) | 1 (5%) | 1.0 |

**Table 2** $CHA_2DS_2VASc$ score in patients with atrial fibrillation on admission ($N = 30$)

| $CHA_2DS_2VASc$ score | *N* |
|---|---|
| 0 | 1 |
| 1 | 3 |
| 2 | 3 |
| 3 | 11 |
| 4 | 4 |
| 5 | 4 |
| 6 | 3 |
| 8 | 1 |

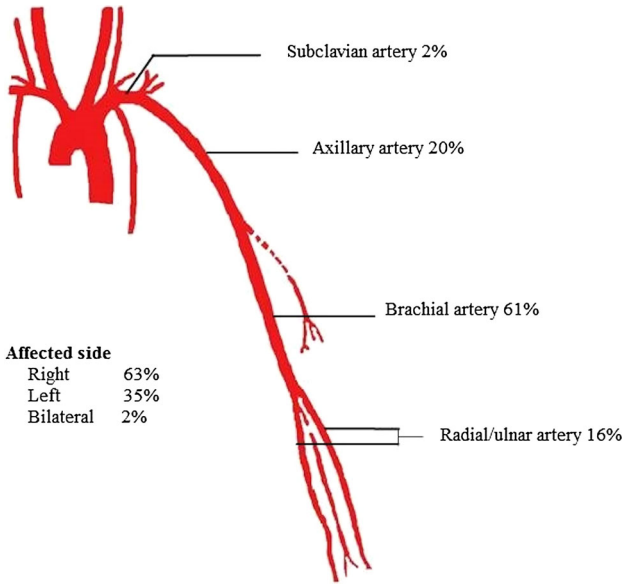


**Fig. 1** Level of thromboembolic occlusion and affected side

concomitant sepsis (HIV and endocarditis and infection of unknown origin): They were not offered surgical treatment, but the diagnosis of upper limb thromboembolism was confirmed by contrast-enhanced CT.

Altogether, seven of the 38 patients (18%) who underwent surgical treatment had a perioperative complication: postoperative bleeding (3 patients), persisting ischemia (3 patients) and compartment syndrome (one patient). Re-intervention was necessary in six of 38 patients (16%): Five went back to theater to stop bleeding, redo thromboembolectomy or fasciotomy and one was successfully treated with thrombolysis. No amputations, primary or later, were performed in any of the patients.

Echocardiography was performed in 23 patients (47%): In four (8%) a cardiac thrombus was detected, and two of these patients had a post-infarct sequela with a hypokinetic or aneurysmal left ventricle and one had a high-grade aortic valve stenosis. Long-term ECG monitoring was only

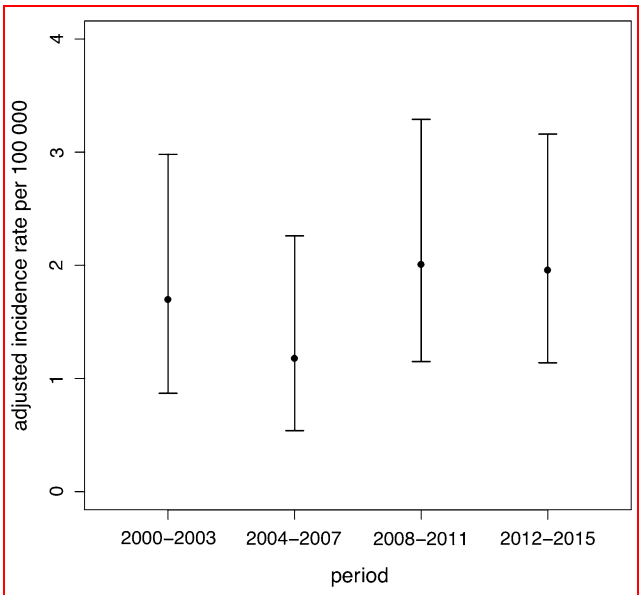


**Fig. 2** Adjusted incidence rate with confidence intervals

performed in 2 of the 29 patients (11%) without AF on admission; AF was detected in one of these patients. Only 8 patients (16%) underwent specific testing for coagulation disorders, and antiphospholipid syndrome was confirmed in two patients (4%).

## Crude and adjusted incidence trends

The crude incidence rate for acute upper limb thromboembolism for the whole study period was 1.4 per 100,000 per year in persons > 20 years. The adjusted incidence rate for the period, adjusted according to the Norwegian population, was 1.6 per 100,000 per year (95% confidence interval (CI) 1.2–2.2), ranging from 1.2 in the period from 2004 to 2007 (95% CI 0.5–2.3) to 2.0 in 2008–2011 (95% CI 1.1–3.3). The adjusted incidence rate did not change significantly through the period studied (Fig. 2).

## Mortality and relative survival

Altogether, 4 of 49 (8%) patients died within 30 days, including the two patients that were admitted with serious concomitant septicemia. The remaining two patients died from coronary ischemia or a pulmonary embolus. At discharge, 27 of the surviving 45 patients (60%) were on anticoagulation therapy, and all but one of the patients had AF.

One-year actual survival was 78% (38 of 49 patients). Figure 3 depicts relative survival. The median follow-up time was 32 months. After 10 years of follow-up the relative survival was 60%. Long-term survival in patients

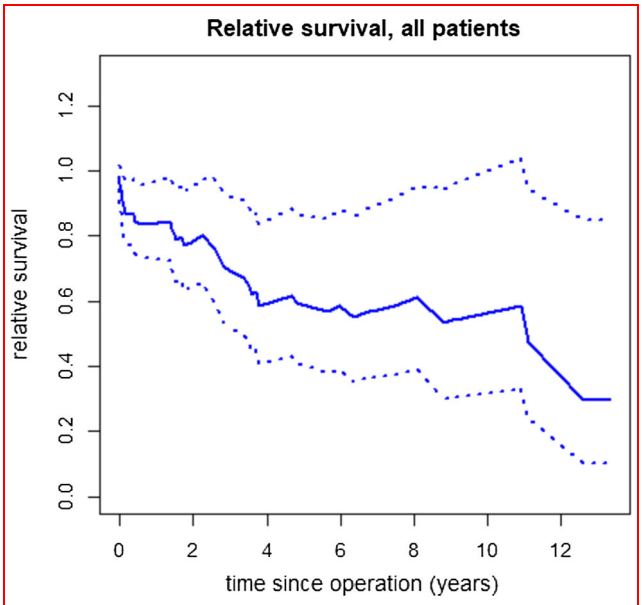


**Fig. 3** Relative survival estimating the ratio of survival in the patient group versus the overall survival in a normal population with the same age, gender and birth year distribution as the patient group, with confidence intervals (dotted lines)

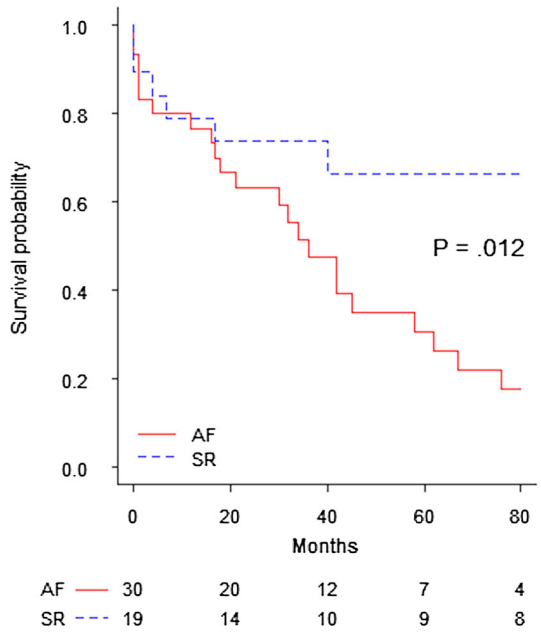


**Fig. 4** Long-term survival in patients with and without AF

without AF on the initial admission was significantly better than in patients with AF (log-rank, $P = .012$) (Fig. 4).

### Late-occurring complications

Later thromboembolic events (> 30 days) were registered in altogether 12 of 45 patients (27%) (Table 3) after a median of 251 days (range 86–2080): Seven of these patients had AF and eight were on warfarin, but only one patient had an INR within therapeutic range.

Re-occlusion later than 30 days was noted in three patients (7%). One had a re-occlusion after 31 days. He had antiphospholipid syndrome and was non-compliant regarding anticoagulation and was re-treated with thrombolysis. The other two re-occlusions occurred after 2.2 and 4 years, respectively. Both were on warfarin but had an INR < 1.9. Surgical thromboembolectomy was performed and was successful in both cases.

**Table 3** Thromboembolic events after 30 days in the study population ($N = 49$)

| Site of thromboembolic event | *N* |
|---|---|
| Upper limb | 3 (6%) |
| Lower limb | 1 (2%) |
| Myocardial | 2 (4%) |
| Cerebral | 6 (12%) |

## Discussion

The adjusted incidence rate for acute upper limb thromboembolism was 1.6/100,000 per year and was stable throughout the period studied. The older population-based studies, also of Nordic origin, report somewhat lower incidence rates: 1.1/100,000 per year in a Swedish study published in 1984 and 1.3/100,000 per year in a Finnish study from 1995 [9, 10]. One may theorize that the higher incidence in our study reflects the increasing incidence of AF. The incidence rate of AF in the studied population is not known, but another Scandinavian study demonstrated a threefold increase in the incidence rate of AF in the time period from 1983 to 2012 [19].

Interestingly, a far higher incidence rate of acute upper limb thromboembolism than in any of the other studies (3.3–5.2/100,000 per year) was reported in a more recent Danish study [8]. The studies from Denmark and Finland are limited to patients that underwent surgical treatment and are therefore not pure population-based studies [8, 10]. Although the Danish study was nationwide, it was based on the National Vascular Registry and National Registry of Patients and the latter registry has a questionable validity [20]. The population basis of the studies from Sweden and Finland was inadequately described [9, 10]. Women with acute upper limb thromboembolism are generally reported to be older than men, but not significantly in our material [21].

Acute upper limb thromboembolism is per se not a deadly disease, but patients may die of diseases that caused

the thromboembolism such as AF and subsequent thromboembolism to the brain, myocardial infarction, valvular disease and septicemia and they have an excess mortality when compared to the age- and sex-matched population. The subgroup of patients with AF had the worst outcome, but had a significantly higher median age than the group of patients without AF. It is known that patients with AF have excess mortality and in a recent report concomitant diseases of non-thromboembolic origin contributed most to the excess mortality in AF [22]. None of the study patients were in need of amputation; others also report a low risk of amputation ranging from 2‰ to 3.6% [5, 8, 10, 23]. Again, the Danish study reports a higher risk than the other studies. The low risk of amputation is due to a rich network of collaterals capable of upholding sufficient perfusion, especially the scapular anastomosis where several arteries contribute [24]. Due to the low amputation risk, some advocate a nonsurgical approach even though this increases the risk of a poorer functional outcome [25].

Surprisingly few of the patients from the first 12 years of the study underwent long-term ECG monitoring, echocardiography or examination for coagulation disorders. AF is considered to be causative in a majority of patients with the disorder and may have been underestimated, as patients with paroxysmal atrial fibrillation might not be detected due to the lack of long-term ECG monitoring. Risk factors such as arterial hypertension, ischemic cardiac disease, cerebrovascular disease and earlier acute thromboembolic events are also overrepresented in our study population as in others [2]. Today, the local procedure protocol includes mandatory imaging (CT or ultrasound), ECG (including long-term monitoring), echocardiography and screening for coagulation disorders in all patients with acute upper limb thromboembolism.

A majority of the patients had AF on admission (61%), and AF was known as a preexisting condition in most of these patients. Guidelines that strongly recommended anticoagulation in AF were published in 2001; despite this, a minority of AF patients were on anticoagulation therapy on admission and few of these were within therapeutic range [26]. The notes failed to give a satisfactory explanation as to why AF patients were not anticoagulated. The $CHA_2DS_2VASc$ score is generally used to predict the risk of stroke in AF and to determine if oral anticoagulation is indicated [15]. Today, the consensus is to consider anticoagulation in patients with a score of 1 and it is indicated in patients with a score of two or more. Thus, according to the recommendations of today, the study patients with AF were seriously undertreated and were subsequently at an increased risk of thromboembolism. Recommendations on anticoagulation in AF have varied throughout the study period, and anticoagulation carries an increased risk of bleeding that will have to be addressed before commencing therapy [27]. Most of the patients on anticoagulation therapy, on admission and later, were treated with warfarin. It has been established that DOAC is not inferior to warfarin in reducing stroke and systemic embolization in AF [28]. DOAC is increasingly utilized as the risk of adverse effects is lower and patient adherence may be better [29].

A substantial proportion of patients (39%) did not have AF on admission. Cardiac embolism due to AF is and has been considered the major cause of acute upper limb thromboembolism, and as mentioned earlier, a majority of patients were not properly tested to rule out AF. However, several other sources of embolism do exist: paradoxical emboli through a persistent foramen ovale, cardiac emboli not caused by AF (e.g., post-myocardial infarction, myxoma, valvular disease) and atheromatous embolization from arteries [1, 8, 30, 31]. Coagulation disorders may contribute to thrombosis and subsequent embolization [32]. It is undecided what the optimal treatment for patients with atheromatous embolization is, but for most of the other potential causes anticoagulation significantly lowers the risk of subsequent thromboembolic events [33].

Very little has been published on the risk of subsequent thromboembolism in acute upper limb thromboembolism [23], although one population-based study found an increased risk of stroke [8]. In our experience, the risk of a new thromboembolic event was high (27%) and was evenly distributed between patients with and without AF. It seems prudent to advocate anticoagulation in all patients with acute upper limb thromboembolism if no obvious contraindications. As for all patients with symptomatic arteriosclerosis, statin therapy is recommended [34].

## Limitations

The study was retrospective and included a limited number of patients, but the population at risk was well defined. A limitation of all studies on acute upper limb thromboembolism, including our own, is that patients not admitted to the hospital will be missed, e.g., old multimorbid nursing home patients not being referred to hospital. In four patients the clinical diagnosis was not confirmed radiologically or on operation, thus potentially leading to an overestimation of thromboembolism rates.

## Conclusion

We found a stable incidence rate of acute upper limb thromboembolism from 2000 to 2015. Most of the patients with AF were inadequately anticoagulated. A quarter of the patients experienced a later thromboembolic event, and lifelong anticoagulation should be considered in all patients with acute upper limb thromboembolism.

## References


1. Eyers P, Earnshaw JJ (1998) Acute non-traumatic arm ischaemia. Br J Surg 85:1340–1346
2. Andersen LV, Lip GY, Lindholt JS et al (2013) Upper limb arterial thromboembolism: a systematic review on incidence, risk factors, and prognosis, including a meta-analysis of risk-modifying drugs. JTH 11:836–844
3. Hart RG, Pearce LA, Aguilar MI (2007) Meta-analysis: antithrombotic therapy to prevent stroke in patients who have nonvalvular atrial fibrillation. Ann Intern Med 146:857–867
4. Stonebridge PA, Clason AE, Duncan AJ et al (1989) Acute ischaemia of the upper limb compared with acute lower limb ischaemia; a 5-year review. Br J Surg 76:515–516
5. Skeik N, Soo-Hoo SS, Porten BR et al (2015) Arterial embolisms and thrombosis in upper extremity ischemia. Vasc Endovasc Surg 49:100–109
6. Conte MS, Pomposelli FB, Clair DG et al (2015) Society for Vascular Surgery practice guidelines for atherosclerotic occlusive disease of the lower extremities: management of asymptomatic disease and claudication. J Vasc Surg 61:2s–41s
7. Aboyans V, Ricco JB, Bartelink MEL et al (2018) Editor's choice—2017 ESC guidelines on the diagnosis and treatment of peripheral arterial diseases, in collaboration with the european society for vascular surgery (ESVS). Eur J Vasc Endovasc Surg 55:305–368
8. Andersen LV, Mortensen LS, Lindholt JS et al (2010) Upper-limb thrombo-embolectomy: national cohort study in Denmark. Eur J Vasc Endovasc Surg 40:628–634
9. Dryjski M, Swedenborg J (1984) Acute ischemia of the extremities in a metropolitan area during one year. J Cardiovasc Surg 25:518–522
10. Pentti J, Salenius JP, Kuukasjarvi P et al (1995) Outcome of surgical treatment in acute upper limb ischaemia. Ann Chir Gynaecol 84:25–28
11. Andrade J, Khairy P, Dobrev D et al (2014) The clinical profile and pathophysiology of atrial fibrillation: relationships among clinical features, epidemiology, and mechanisms. Circ Res 114:1453–1468
12. von Elm E, Altman DG, Egger M et al (2007) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet (London, England) 370:1453–1457
13. Reite A, Soreide K, Ellingsen CL et al (2015) Epidemiology of ruptured abdominal aortic aneurysms in a well-defined Norwegian population with trends in incidence, intervention rate, and mortality. J Vasc Surg 61:1168–1174
14. Sandvik OM, Soreide K, Gudlaugsson E et al (2016) Epidemiology and classification of gastroenteropancreatic neuroendocrine neoplasms using current coding criteria. Br J Surg 103:226–232
15. Lip GY, Nieuwlaat R, Pisters R et al (2010) Refining clinical risk stratification for predicting stroke and thromboembolism in atrial fibrillation using a novel risk factor-based approach: the euro heart survey on atrial fibrillation. Chest 137:263–272
16. R Core Team (2017) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/. Accessed 4 Dec 2017.
17. Pohar M, Stare J (2006) Relative survival analysis in R. Comput Methods Programs Biomed 81:272–278
18. Aragon TJ (2017) epitools: epidemiology tools. R package version 0.5-10. https://CRAN.R-project.org/package=epitools. Accessed 4 Dec 2017.
19. Schmidt M, Ulrichsen SP, Pedersen L et al (2016) 30-year nationwide trends in incidence of atrial fibrillation in Denmark and associated 5-year risk of heart failure, stroke, and death. Int J Cardiol 225:30–36
20. Lasota AN, Overvad K, Eriksen HH et al (2017) Validity of peripheral arterial disease diagnoses in the Danish National Patient Registry. Eur J Vasc Endovasc Surg 53:679–685
21. Ljungman C, Adami HO, Bergqvist D et al (1991) Time trends in incidence rates of acute, non-traumatic extremity ischaemia: a population-based study during a 19-year period. Br J Surg 78:857–860
22. Andersson T, Magnuson A, Bryngelsson IL et al (2013) All-cause mortality in 272,186 patients hospitalized with incident atrial fibrillation 1995-2008: a Swedish nationwide long-term case-control study. Eur Heart J 34:1061–1067
23. Kim HK, Jung H, Cho J et al (2015) Therapeutic outcomes and thromboembolic events after treatment of acute arterial thromboembolism of the upper extremity. Ann Vasc Surg 29:303–310
24. Srebenik HH, Circulation Collateral (2002) In: Srebenik HH (ed) Concepts in anatomy. Springer, Boston, pp 201–206
25. Wong VW, Major MR, Higgins JP (2016) Nonoperative management of acute upper limb ischemia. Hand (New York, NY) 11:131–143
26. Fuster V, Ryden LE, Asinger RW et al (2001) ACC/AHA/ESC guidelines for the management of patients with atrial fibrillation. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines and Policy Conferences (Committee to develop guidelines for the management of patients with atrial fibrillation) developed in collaboration with the North American Society of Pacing and Electrophysiology. Eur Heart J 22:1852–1923
27. Pisters R, Lane DA, Nieuwlaat R et al (2010) A novel user-friendly score (HAS-BLED) to assess 1-year risk of major bleeding in patients with atrial fibrillation: the Euro Heart Survey. Chest 138:1093–1100
28. Bruins Slot KM, Berge E (2018) Factor Xa inhibitors versus vitamin K antagonists for preventing cerebral or systemic embolism in patients with atrial fibrillation. Cochrane Database Syst Rev 3:CD008980
29. Zirlik A, Bode C (2017) Vitamin K antagonists: relative strengths and weaknesses vs. direct oral anticoagulants for stroke prevention in patients with atrial fibrillation. J Thromb Thrombolysis 43:365–379
30. Deguara J, Ali T, Modarai B et al (2005) Upper limb ischemia: 20 years experience from a single center. Vascular 13:84–91
31. Kronzon I, Saric M (2010) Cholesterol embolization syndrome. Circulation 122:631–641
32. Maino A, Rosendaal FR, Algra A et al (2015) hypercoagulability is a stronger risk factor for ischaemic stroke than for myocardial infarction: a systematic review. PLoS ONE 10:e0133523
33. Giacalone G, Abbas MA, Corea F (2010) Prevention strategies for cardioembolic stroke: present and future perspectives. Open Neurol J 4:56–63
34. Hiratzka LF, Bakris GL, Beckman JA et al (2010) 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines

for the diagnosis and management of patients with Thoracic Aortic Disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation 121:e266–e369