



The path from ictus to Neurosurgery: chronology and transport logistics of patients with aneurysmal subarachnoid haemorrhage in the South-Eastern Norway Health Region

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Abstract

Background Guidelines state that patients with aneurysmal subarachnoid haemorrhage (aSAH) require neurosurgical treatment as early as possible. Little is known about the time frame of transport from the ictus scene to Neurosurgery in large, partially remote catchment areas. We therefore analysed the chronology and transport logistics of aSAH patients in the South-Eastern Norway Health Region and related them to the frequency of aneurysm rebleed and 1-year mortality.

Methods Retrospective analysis of aSAH patients bleeding within our region admitted to Neurosurgery during a 5-year period. Date, time and site of ictus and arrival at Neurosurgery, distance and mode of transport and admission were obtained from our institutional quality register and the emergency medical communication centre log. We scored the patients' clinical condition, rebleeds and 1-year mortality.

Results Five hundred forty-four patients were included. Median time from ictus to arrival Neurosurgery was 4.5 h. Transport by road ambulance was most common at distances between the ictus scene and Neurosurgery below 50 km, whereas airborne transport became increasingly more common at larger distances. Direct admissions, frequency of intubation and airborne transport to Neurosurgery increased with the severity of haemorrhage, leading to shorter transport times. The risk of rebleed was 0.8%/hour of transport. The rebleed rate was independent of distances travelled, but increased with the severity of aSAH, reaching up to 6.54%/hour in poor-grade patients. Distance and time of transport had no impact on 1-year mortality, whereas poor-grade aSAH and rebleed were strong predictors of mortality.

Conclusions Poor-grade aSAH patients have a high risk of rebleed independent of the distance between the ictus scene and Neurosurgery. As rebleeding triples 1-year mortality, patients with Glasgow Coma Score < 9 with suspected aSAH should be admitted directly to Neurosurgery without delay after best possible cardiovascular and airway optimisation on site by competent personnel.

Keywords Aneurysmal subarachnoid haemorrhage · Transport · Rebleeding · Emergency medicine · Hunt and Hess score

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Abbreviations

aSAH	Aneurysmal subarachnoid haemorrhage
CI	Confidence interval
CT	Computed tomography
CTA	Computed tomography angiography
GCS	Glasgow Coma Scale
HEMS	Helicopter Emergency Medical Services
OR	Odds ratio

Introduction

Aneurysmal subarachnoid haemorrhage (aSAH) is a life-threatening event that usually strikes without any prior

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warning. When an intracranial aneurysm ruptures, the intracranial pressure (ICP) rises abruptly, often to such an extent that the cerebral circulation ceases [14]. In order to survive the haemorrhage, the patient's ICP needs to decrease spontaneously to acceptable limits within few minutes. The high ICP may cause tissue damage and brain oedema. Furthermore, the blood in the subarachnoid space, and possibly also in the ventricular system, inhibits the circulation of cerebrospinal fluid, thereby potentially leading to acute hydrocephalus. These mechanisms roll on unhindered unless the patient is admitted to Neurosurgery where these secondary events can be managed. Thus, the more time elapsing between the ictus and access to neurosurgical treatment, the longer time a patient is subjected to mechanisms that may influence outcome negatively.

Aneurysm rebleed represents a second, often devastating blow with a high negative impact on outcome [4, 20, 22] and accounts for about 60% of aSAH mortality [10]. Hence, the most important acute treatment of aSAH is to prevent rebleeding by aneurysm repair. Although most authors report the risk of aneurysm rebleed within 24 h, the highest risks of rebleeding may be present within the first 6 h after ictus [10, 20]. Most studies investigated the timeframe of rebleed after hospital admission, whereas the timely occurrence of rebleed after the ictus is more obscure. Swift transport to Neurosurgery may decrease the time until aneurysm repair and therefore potentially prevent rebleeds. European guidelines for the treatment of aSAH hence advocate treatment "as early as logistically and technically possible" [18].

Transport logistics are dependent on geographical factors, the size of catchment area a neurosurgical unit is responsible for and local infrastructure. With large distances to a neurosurgical centre, patients may often be transported to their closest hospital, being diagnosed or confirmed having aSAH there, stabilised, and then transferred to a neurosurgical unit. Another model is direct transport of suspected aSAH patients from the scene to Neurosurgery without prior local confirmation of diagnosis.

Little is known about the time frame of transport from the ictus scene to neurosurgical service in larger, partially remote catchment areas. The aim of the present paper is to retrospectively analyse the chronology and transport logistics of aSAH patients in the South-Eastern Norway Health Region and relate them to the frequency of aneurysm rebleed and 1-year mortality.

Material and methods

The Department of Neurosurgery, Oslo University Hospital, Rikshospitalet, Norway, is the sole, high-volume, tertiary/quaternary centre in the South-Eastern Norway Health Region. All patients admitted with acute non-traumatic

aSAH within the region during the time period 01 January 2013–31 December 2017 were eligible. The area of the region equals the size of Austria and Switzerland combined with 2.8 million people living within its borders. Figure 1 illustrates the South-Eastern Norway Health Region and the localisation of Neurosurgery, hospitals and helicopter bases within it.

We excluded cases with unknown time or site of ictus, cases with no initial CT scans available and cases where the time between ictus and arrival at the neurosurgical department exceeded 14 days. We also excluded aSAH from aneurysms on feeders to arteriovenous malformations and cases that were transferred to our department after aneurysm repair elsewhere.

Data were acquired from our institutional quality register for neurovascular cases. Data entry for the quality register was obtained from medical records and the emergency medical communication centre log. For the present study, we extracted the following data: date, time and site of ictus, mode of transport (road or airborne), first hospital the patients were transported to and time of diagnosis as established by the time of the first computed tomography (CT/CT angiography). The clinical condition was expressed by the Hunt and Hess grade [8] and the Glasgow Coma Scale [21] (GCS, at first contact of professionals with the patient and again at arrival at the neurosurgical department or just prior to intubation). We also registered if the patients arrived intubated at our hospital, and if so, where the intubation was performed. We scored any clinical and/or radiological indications of rebleed and where the rebleed occurred. A second thunderclap headache with or without loss of consciousness, sudden deterioration of GCS with or without blood pressure response, was considered a clinical rebleed. One-year mortality (regardless of cause) was also listed. Transport distances were given in kilometres when using the shortest road connections.

All aSAH patients are treated according to our institutional guidelines [17]. These include the administration of 1 g intravenous tranexamic acid as soon as diagnosis is established and 2 h later, thereafter every sixth hour until the aneurysm is repaired [5].

This study was approved as a quality project by the institutional data protection officer (number 17/2093) and did not require informed consent.

Statistics

Statistical analysis was performed in SPSS v.25 (SPSS Inc., Chicago, IL, USA). Continuous, not normally distributed data are presented with median and range and the Kruskal-Wallis test was used to compare differences between groups. Categorical variables are presented by frequencies or percentages and the chi-square test was used to compare differences between groups. Continuous, normally distributed variables were presented by mean with standard deviation and independent samples *t* test was used to compare differences between

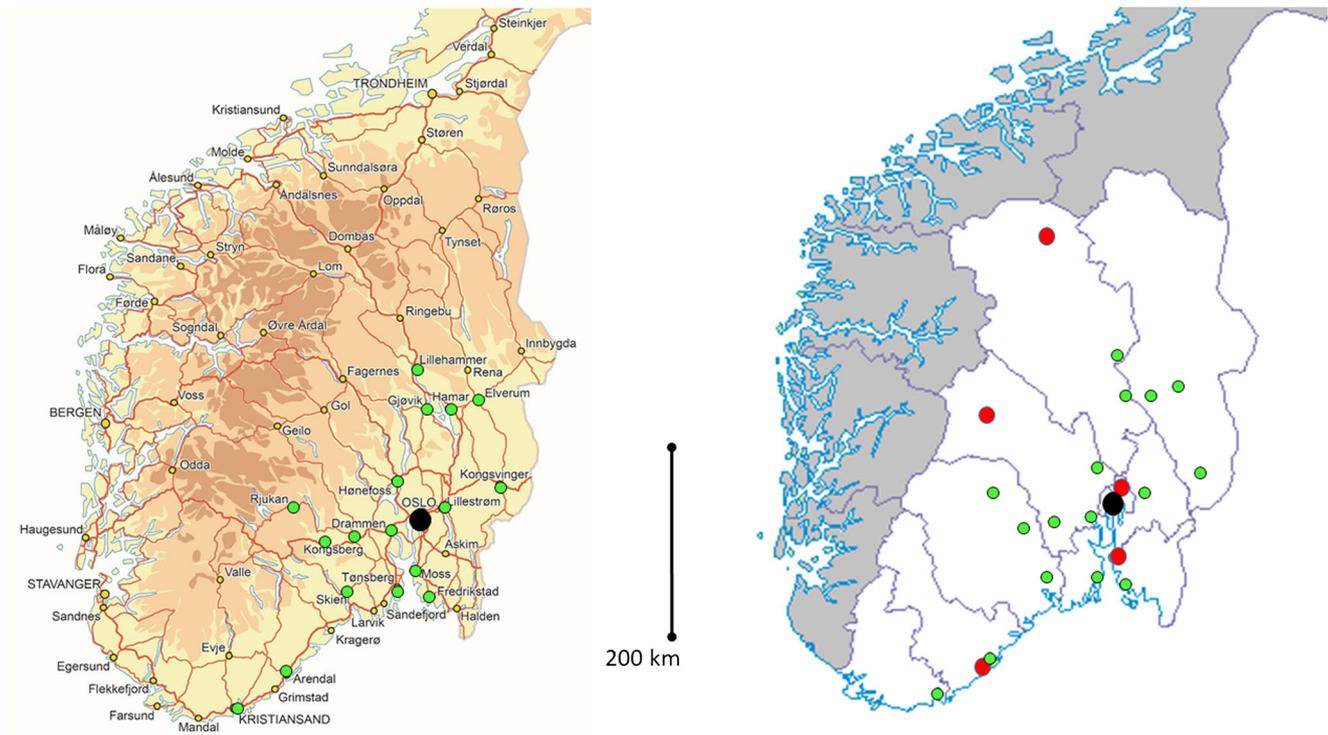


Fig. 1 Southern Norway. South-Eastern Norway Health Region is shown in white with the location of Neurosurgery (black dot), its hospitals (green dots) and its helicopter bases (red dots). Purple lines show the borders

between counties. Blue framing indicates coastline. Maps with permission Kartverket, Geonorge, Illustrasjonskart

groups. Univariate binary logistic regression analysis was used for calculating odds ratios (OR) with confidence intervals (CI). A significance level of $p < 0.05$ was adopted.

excluded in accordance with the criteria we presently defined, leaving a total of 544 aSAH cases that were included in the study. There were 368 (67.6%) females and 176 (32.4%) males with a median age of 58 years (1–95 years).

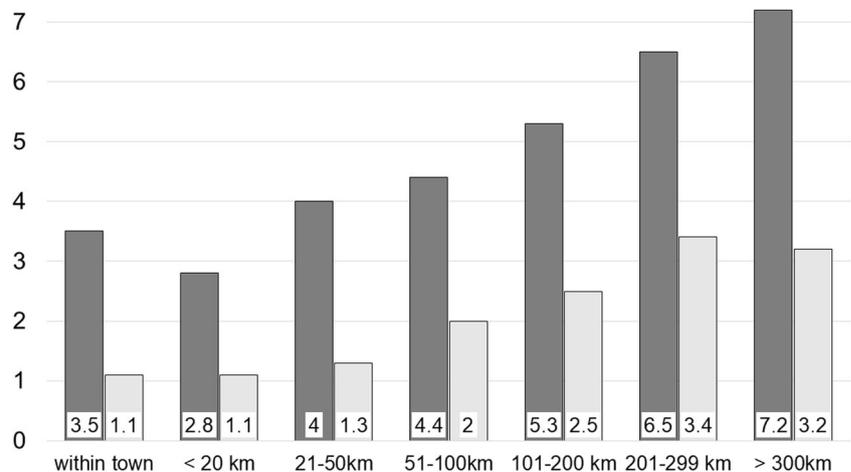
Results

A total of 774 patients with non-traumatic SAH not caused by arteriovenous malformation or fistula were admitted during the time period of the study. In 179/774, no aneurysm was identified. Of the remaining 595 patients with aSAH, 51 were

Transport times

Median time from ictus to arrival Neurosurgery was 4.5 h (0.5–334.3 h). Patients transported directly from the site of ictus (direct admission, $n = 94$; 17.3%) arrived significantly faster at Neurosurgery than the 450 patients that were

Fig. 2 Median transport times (hours) from the time of ictus to arrival Neurosurgery (dark bars) and from the time of diagnosis at a local hospital for patients transferred (indirect admissions, light grey bars), in relation to distance between the ictus scene and Neurosurgery



transferred from a local hospital (indirect admission) (median 1.6 h after aneurysm rupture (range 0.5–199.3 h) versus median 5.2 h (range 1.0–334.3 h), $p < 0.001$). In the 450 cases with indirect admission, the time from diagnosis to arrival Neurosurgery was median 2.0 h (range 0.3–78.8 h). Figure 2 shows median transport times from the time of ictus and from the time of diagnosis, respectively, in relation to distance between the ictus scene and Neurosurgery.

Transport times increased with distance between the site of ictus and Neurosurgery ($p < 0.001$). However, there were no significant differences in transport times for distances up to 100 km. Likewise, the transport times for distance categories larger than 100 km were not significantly different. When comparing time from ictus to arrival Neurosurgery for those bleeding within a radius of 20 km from Neurosurgery versus those bleeding at locations further away than 200 km, there was only a moderate difference in transport time between these two extremes (median 3.3 h versus median 6.9 h).

Table 1 shows that median transportation times were independent of the weekday, holidays and of the daytime of ictus.

Most patients had a stable GCS from the time of ictus and until arrival at Neurosurgery (79.3%); however, 13.1% had experienced a fall in GCS during transport while 7.6% improved their GCS during transport. Declines in the GCS were independent of the distance between the site of ictus and Neurosurgery ($p = 0.962$) as well as of the transportation times ($p = 0.799$).

Mode of transport

The mode of transport changed in relation to distance from Neurosurgery. Transport by road ambulance was most common at distances below 50 km. Airborne transport with helicopter became increasingly more used beyond 50 km, and became predominant for distances in excess of 100 km (Fig. 3).

The frequency of direct admission to Neurosurgery increased with the severity of haemorrhage in terms of Hunt and Hess grade (chi-square, $p < 0.001$, Fig. 4). Furthermore, airborne transport to Neurosurgery increased with higher Hunt and Hess grades (chi-square, $p < 0.001$, Fig. 4).

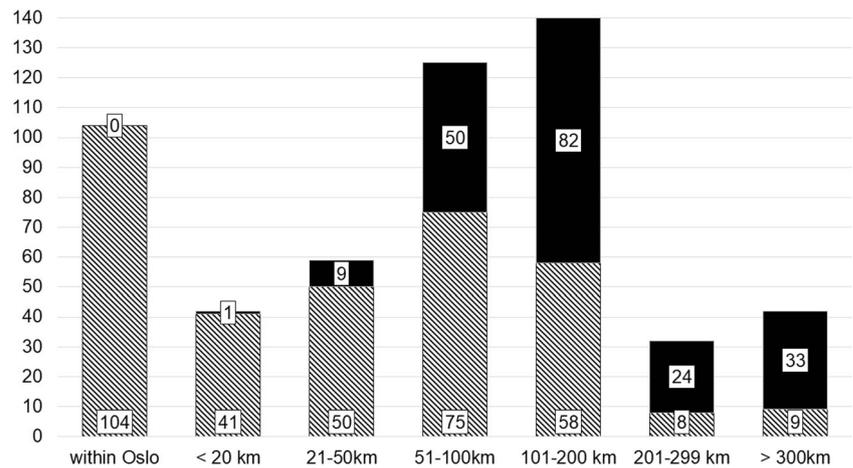
Aneurysm rebleeds

There was no difference in the frequency of aneurysm rebleeds between patients admitted directly (13.1%) and patients that were transferred from their local hospital (15.7%; $p = 0.739$), and indirect admission was not a predictor of rebleed. Transport times decreased in accordance with the Hunt and Hess grade ($p < 0.001$, Kruskal-Wallis analysis, Fig. 5). The hourly rebleed rate, however, rose vastly with the Hunt and Hess grade ($p < 0.001$, Kruskal-Wallis analysis, Fig. 5).

Table 1 Median transport times (hours) for the different weekdays, holidays, as well as the daytime of ictus

Weekday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Holiday	<i>p</i>
Number of patients	73	86	75	79	87	73	71	81	
Ictus to arrival (median, range)	4.6 (0.5–236.9)	4.5 (1.0–334.3)	4.1 (0.7–180.3)	5.1 (1.0–226.0)	5.3 (0.8–247.8)	4.3 (0.5–250.7)	4.7 (0.5–244.8)	4.4 (0.4–244.8)	0.739
Indirect admission (median, range)	1.8 (0.4–78.8)	2.1 (0.4–35.9)	1.8 (0.4–35.4)	2.0 (0.4–8.8)	2.1 (0.3–52.0)	2.1 (0.3–8.4)	2.0 (0.3–34.8)	2.0 (0.3–34.8)	0.902
Daytime of ictus	00:00–02:59	03:00–05:59	06:00–08:59	09:00–11:59	12:00–14:59	15:00–17:59	18:00–20:59	21:00–23:59	
Number of patients	19	17	49	97	112	94	97	59	
Ictus to arrival (median, range)	4.0 (1.3–92.1)	4.5 (0.5–24.9)	4.1 (1.0–244.8)	5.3 (0.7–274.8)	4.4 (0.7–260.7)	4.2 (0.6–334.3)	4.5 (0.5–151.0)	4.1 (0.5–330.0)	0.200
Indirect admission (median, range)	2.0 (0.3–6.5)	1.3 (0.6–3.8)	2.0 (0.3–35.9)	2.6 (0.4–51.0)	2.1 (0.4–23.8)	1.6 (0.5–78.8)	2.1 (0.3–23.8)	1.6 (0.4–13.5)	0.134

Fig. 3 Number of patients transported to Neurosurgery by road ambulance (grey-shaded bars) versus those transported airborne with helicopter (black bars) within the various distance categories between ictus scene and Neurosurgery



The hourly rebleed rate prior to arrival at Neurosurgery was independent of the distance to Neurosurgery (Fig. 6, chi-square, $p = 0.777$).

Consequently, distance between the site of ictus and Neurosurgery was not a predictor of aneurysm rebleed. Transport time from ictus until arrival at Neurosurgery was a weak, but significant risk factor for rebleed with an OR of 1.008 (95% CI 1.004–1.012, $p < 0.0001$), indicating that the risk of rebleed increased with 0.8% per hour transport time. Hunt and Hess grade was also a predictor of rebleed with an OR of 1.490 (95% CI 1.174–1.890; $p = 0.001$).

Intubation

Of the 544 patients, 201 (36.9%) arrived intubated at Neurosurgery. Most of these 201 patients were intubated in a local hospital (63%), whereas 32.5% were intubated at the site of ictus and 4.5% were intubated during transport. Their mean GCS was 5.8 ± 3.3 just prior to intubation, which was significantly lower than in the 343 patients who were breathing spontaneously (not intubated) on arrival at Neurosurgery

(13.6 ± 2.6 , $p < 0.0001$). Among the 343 patients arriving at Neurosurgery, non-intubated 7.3% had a GCS of ≤ 9 .

Among the intubated patients, the majority had a GCS of ≤ 9 (76.1%), whereas 19.0% had a GCS of ≥ 12 just prior to intubation. Most of them had a stable GCS from the time of ictus until intubation (78.1%), whereas 20.4% had a decline in GCS from the ictus to intubation. Merely 1.5% had improved their GCS from the time of ictus to intubation. In addition to more intubated patients having experienced a change in GCS prior to intubation, their deterioration was more pronounced than in those that were not intubated (decline in GCS – 4.3 ± 4.0 median – 4.5 (– 12 to + 5) versus – 0.97 ± 4.6 median – 1.0 (– 12 to + 11), $p < 0.001$).

The rate of intubated patients increased with higher Hunt and Hess grades (Fig. 7) and did not differ significantly between airborne- and road-based transport in high-grade patients (Hunt and Hess grades 4+5, Fig. 7). Distances between the site of ictus and Neurosurgery in excess of 100 km increased the chance of intubation by 43% (OR 1.432, 95% CI 1.004–2.042, $p = 0.047$). When correcting for Hunt and Hess grade in a multivariate binomial regression model, the chance

Fig. 4 Hunt and Hess grade [8] in relation to number of patients admitted directly to Neurosurgery (red bars), number of patients transferred from their local hospital (blue bars) and percentage of patients transported airborne within each category of Hunt and Hess grade (black bars)

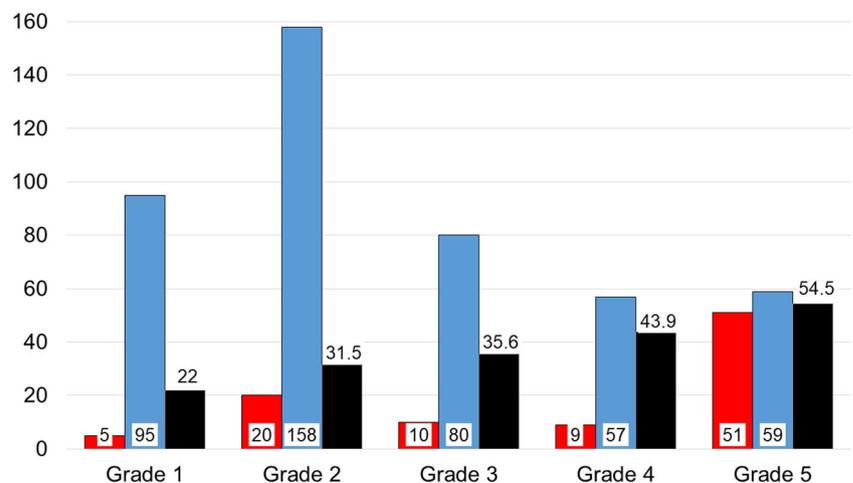
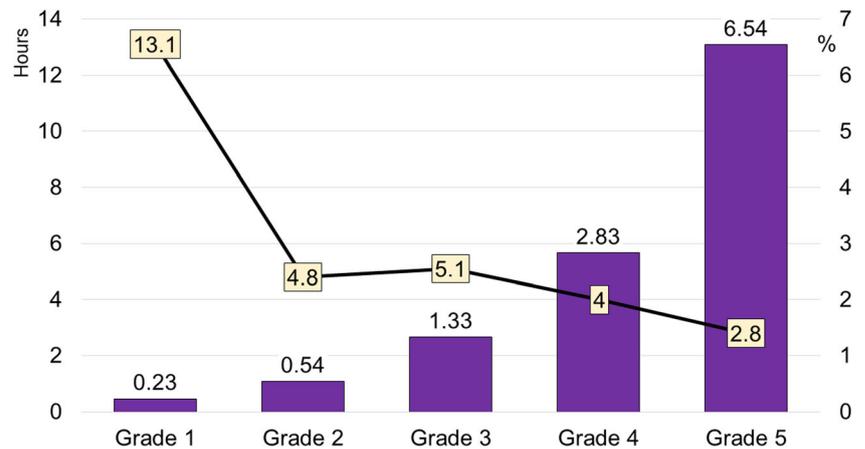


Fig. 5 Hunt and Hess grade [8] in relation to transport time from ictus to arrival Neurosurgery (black line, median time (hours) and hourly rebleed rate prior to arrival Neurosurgery (violet bars)



of intubation at distances > 100 km was more than doubled with an OR of 2.238 (95% CI 1.294–3.871, $p = 0.004$).

Intubation was performed in the majority of patients that suffered a rebleed (73.3%). The event of rebleeding almost 12-folded the chance of intubation independently of Hunt and Hess grade and distance to Neurosurgery with an OR of 11.762 (95% CI 4.589–30.148; $p < 0.0001$).

One-year mortality

For all 544 patients combined, the 1-year mortality regardless of cause and regardless of level of active treatment offered at Neurosurgery was 21.9%. There were no differences in mortality regarding the weekday and daytime of arrival to Neurosurgery ($p = 0.677$). Mortality was 22.2% in patients arriving between 6 AM and 6 PM versus 21.6% in those arriving between 6 PM and 6 AM. Mortality in direct admissions was 36.8% and indirect admissions had a mortality of 18.7% ($p < 0.0001$). Patients that suffered a rebleed had significantly higher mortality compared with those without rebleed (43.1% versus 18.6%, $p < 0.0001$). Neither distance between the site of ictus and Neurosurgery, nor transport time was a predictor of mortality ($p = 0.790$ and $p = 0.487$). Hence, in the multivariate model that included Hunt and Hess grade, distance to Neurosurgery, direct admission,

aneurysm rebleed, intubation and transport times, only Hunt and Hess grade and rebleed remained a significant predictor of mortality. In grade 4 patients, the risk of 1-year mortality was almost tripled, whereas the corresponding risk was 14-fold in grade 5 patients (Hunt and Hess grade 4: OR 2.913; 95% CI 1.187–7.149, $p = 0.020$; and Hunt and Hess grade 5: OR 14.066; 95% CI 6.376–31.033; $p < 0.0001$). Rebleeding tripled the risk of 1-year mortality (OR 3.140; 95% CI 1.710–5.766; $p < 0.0001$).

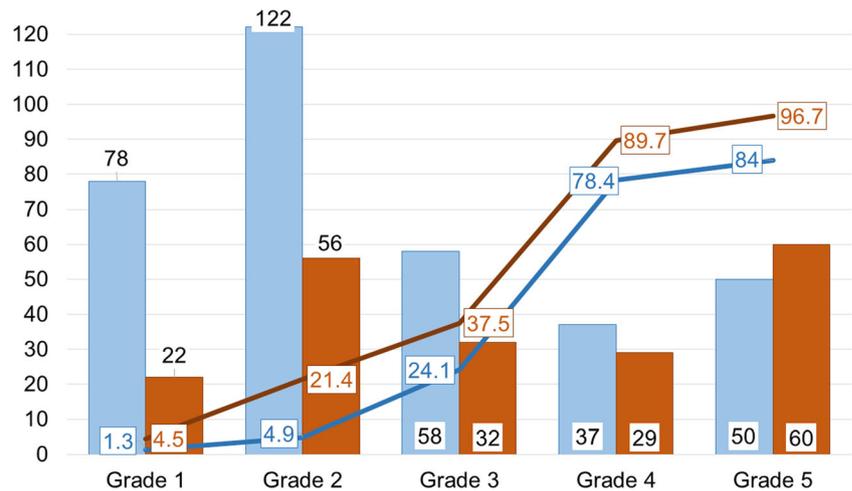
Discussion

The core finding of this study is that the distance between the ictus scene and Neurosurgery is not decisive for the frequency of aneurysm rebleeds or 1-year mortality in aSAH patients. Transport times from the time of ictus until arrival at Neurosurgery did not influence mortality but had a small impact on the risk of rebleeding which increased with 0.8% per hour transport time. Aneurysm rebleed was also dependent on the clinical state of the patient with a hourly rebleed rate of 2.8% in Hunt and Hess 4 patients and 6.5% in Hunt and Hess 5 patients. Rebleeding more than tripled the risk of 1-year mortality.

Fig. 6 Distance between the ictus scene and Neurosurgery in relation to hourly rebleed rate prior to arrival to Neurosurgery (violet bars)



Fig. 7 Hunt and Hess grade [8] in relation to number of patients transported on the road (blue columns) and by air (brown columns) and the rate of patients being intubated prior to arrival at Neurosurgery within each type of transport (blue line: intubation rate in patients with road-bound transport; brown line: intubation rate in patients with airborne transport)



Transport times and distances

Wilson et al. [25] studied transfer times and their effect on outcome in aSAH. Their neurosurgical centre covers an area with the farthest distance being 450 miles (725 km) [25]. Their transfer times were on average 7.7 h from the time of first contact at the local hospital until arrival at their department and hence corresponds to our transport time for indirect admissions, which in comparison was much lower with between 1.1 and 3.2 h. [25]. This difference may be due to larger distances or different modes of transport in the study of Wilson et al. [25] or to different routines for registration of arrival times. Presently, 17.3% were direct admissions, which is lower than the 40.1% emergency department admissions at Johns Hopkins Hospital, Baltimore [13], but higher than the more comparable 12.6% reported by Wilson et al. [25] and the 11.3% reported by Weyhenmeyer et al. [24]. Both reports could not detect any effect of transferral times or direct versus indirect admissions on the occurrence of rebleeding or mortality [24, 25]. Wilson concludes that “protocols should emphasize early resuscitation and stabilization followed by safe transfer rather than a hyperacute transfer paradigm” [25] and nothing in our findings contradicts that notion. The results of Weyhenmeyer et al. gives indications along the same line: they found mortality rates to increase with the distance between the referring hospital and the tertiary centre for each increment of 20 miles and up to 100 miles distance where mortality was more than doubled compared with distances less than 20 miles [24]. However, they attributed this dramatic increase in mortality to competence, with the transferring hospitals lacking stroke centre certifications and thereby providing inadequate cardiovascular and neurological management in the time from symptom onset to arrival at Neurosurgery [13, 24]. This is an argument for staffing of ambulances and helicopters with competent specialists within anaesthesia and emergency medicine when transporting aSAH patients, as is the case in the Scandinavian model. Well-stabilised patients in

safe transfers may be less prone to experience declines in GCS that are not caused by secondary effects of the haemorrhage like acute hydrocephalus. Correspondingly, we presently could not find any relation of GCS deterioration to transport distance or transfer times.

When looking at the subgroup of poor-grade aSAH patients, they are more likely to be admitted directly from the ictus scene [13]. Longer transport times were found to have a clear negative impact on in-hospital mortality in this subgroup [13, 23]. Van Lieshout et al. [23] reported transport times (from the placement of the emergency call to arrival at Neurosurgery) of 262 min in poor-grade patients that died in the hospital versus 71 min in the survivors. These numbers are comparable to those we found in our entire population; however, our transport time in Hunt and Hess grade 5 patients was much shorter with a median of 2.8 h (168 min) independent of distance and direct/indirect admissions. This is possibly due to an increased use of helicopters in transporting patients at distances > 50 km in the present study. Lee et al. [11] found a lower number of referrals and higher mortality during the weekend and increased mortality in those admitted at night time in a large study including 2849 aSAH patients. We cannot corroborate this finding, possibly indicating that emergency services in our catchment area are established on an ubiquitous, 24/7 basis without any suboptimal periods of service and availability.

Mode of transport

By establishing and adequately coordinating an emergency ambulance and helicopter transport system, one may achieve swift transportation of patients within a large geographical area (a circle with a radius of 200 km contains a land area of 125,000 km²) to highly specialised centres for advanced medical treatment. With such a transport system, large patient cohorts can be offered advanced management in settings where short time windows from ictus to invasive treatment

are essential for outcome. Airborne transport can be assumed to be much faster than road-based transport; however, for distances less than 50 km, helicopter transport was not found to be timesaving compared with transport by ambulance [1, 6]. Our scarce use of helicopter for shorter distances hence seems to be sensible. Airborne transport is more dependent on weather conditions; it is expensive and carries a certain risk: the US Federal Aviation Administration identified 62 helicopter accidents claiming 125 lives in a 19-year period [6]. In Norway, 123 helicopter accidents happened during the 65-year period between 1953 and 2018; however, merely 8 were ambulance helicopter accidents with 16 fatalities. On the other hand, ambulance transport by road at high speed also carries certain risks, especially in a harsh climate.

It has been argued that transport per se may represent a danger for the patient [9, 11, 16], vibration and noise in confined spaces having potentially harmful effects on blood pressure and heart rate [19]. In this respect, transport of aSAH patients from the scene by helicopter directly to a neurosurgical centre was found equivalent to ground transportation [9]. Ishikawa et al. [9] also found that patients in poorer clinical status at the scene were more likely to be transported by helicopter rather than on the ground. They could not find any differences in the frequency of cardiac arrest during transport or survival between the patients transported airborne directly from the scene versus those that travelled by ambulance to a local hospital first [9]. This is in line with the findings by Silbergleit et al. [16] who found that patients transported within 8 h of symptom onset had lower GCS scores, but similar outcomes compared with those transported later. One could assume that patients in a poorer clinical condition should have worse outcomes; their findings thereby implying indirectly that swift transportation by air is not only safe and effective, but beneficial for the patient [9, 16]. This should also be true in Norway, especially keeping in mind that the Scandinavian Helicopter Emergency Medical Services (HEMS) are staffed with certified specialists in anaesthesia and intensive care, hence providing the highest level of competence within prehospital and retrieval medicine.

Our increasing use of direct admissions and airborne transport with augmenting Hunt and Hess grades indicates a high level of awareness for the right diagnosis among emergency personnel on site, steering suspected aSAH cases directly to Neurosurgery, an important contribution to survival in the poor-grade group where odds are much worse when symptoms are mistaken for other diagnoses, in particular primary cardiac arrests/cardiac infarctions [23].

Aneurysm rebleed

Our rate of aneurysm rebleed was similar to the rate of 13.6% found by Ohkuma et al. [15], who also reported a peak time for rebleeding within the first 2 h after the ictus. The present

study shows that the risk of early aneurysm rebleed is very closely associated with the clinical condition of the patient. This corroborates with earlier findings [4, 15, 22], although not all studies have found higher rates of rebleed in poor-grade aSAH patients [10, 20]. The shockingly high hourly rebleed that we presently found among our poor-grade patients emphasises the importance of avoiding unnecessary delays in transport, favouring direct transport of this aSAH subpopulation to a Neurosurgical centre where aneurysm repair can be offered on a 24/7 basis. In this respect, it is of utmost importance to ensure that transport is performed safe with best possible cardiovascular and airway optimisation on site by competent personnel, rather than rushing the patient to Neurosurgery under sub-optimal conditions. Naval et al. [13] reported much lower in-hospital mortality in direct admissions compared with transferrals, even though the fraction of poor-grade patients was much higher among the direct admissions.

Even though we did not find different rebleeding rates in direct versus indirect admissions, poor-grade aSAH patients should preferably be transported directly from the site of ictus to Neurosurgery in order to reduce the high risk of rebleed in this aSAH subgroup and further worsen their already grim prognosis. The Hunt and Hess grade is a very strong predictor of outcome and mortality [12, 15]; presently, however, aneurysm rebleed tripled the risk of 1-year mortality even after correction for Hunt and Hess grade. This corroborates with Ohkuma et al. [15] who found 51.4% mortality and zero good recoveries in patients with aneurysm rebleed compared with 18.2% mortality and 41.5% good recoveries among those that were spared for rebleeds.

In contrast, the hourly rebleed risk among aSAH patients in Hunt and Hess grades 1 and 2 is so low that direct transport to a Neurosurgical unit is not warranted. In our study, the risk of rebleed increased only by 0.8%/hour transport time, which contradicts the findings of Wilson et al. who found no association between transfer times and the occurrence of aneurysm rebleed [25]. The subgroup of patients with thunderclap headache/suspected aSAH in good clinical condition can hence be transported to a local hospital for diagnosis and evaluation. With more than 100 different causes other than aSAH, the vast majority of patients seeking medical aid for thunderclap headache will actually not have an aSAH [3], and local triage would prevent overflow admittances to neurosurgical centres and provide adequate local health care targeted against the main neurological problems that caused the headache. However, should aSAH be verified, also good-grade patients should be transported to Neurosurgery without delay. In patients with GCS 15 that have transfer times on the ground of up to 3 h, the transfer may safely be performed in car ambulances [6].

Intubation

Securing free airways and adequate ventilation is mandatory in reducing the secondary effects of aSAH. About one-third of our patients were thus intubated at the scene. Such prehospital intubation of aSAH patients requires high-quality standards in order to be justifiable for the patients in whom haemodynamic control is of utmost importance [2]. At the scene, intubation can be done with low complication rates when performed by experienced prehospital physicians with a background within anaesthesia and intensive care and the benefits will clearly outweigh the risk connected with this procedure in the aSAH group [2]. Representing a safer alternative, HEMS physicians in our service do in general intubate patients prior to transport if it is likely that the need will arise during transport. This likeliness can be linked to the clinical condition of the patient or long transport times. Prehospital intubation should always be carried out after international-accepted guidelines for aSAH patients [2], and in our opinion, the threshold for intubation should be low even in patients with GCS > 9 when transport is expected to be time-consuming, stressful (bad weather and/or evacuation from remote areas) and deterioration in GCS can be expected during transport.

Limitations

This study only accounts for individuals that were admitted to Neurosurgery. With about 12% of aSAH cases dying before reaching any medical attention [7], the actual number of fatalities and mortality due to aneurysm rebleed is certainly higher than what we present. It remains obscure how many of these deaths could have been prevented by early recognition of cause of symptoms at onset or better lines of patient transfer.

We have to presume a certain inaccuracy regarding the time of ictus as it relies on information given by the patient and/or family prone to recall bias. Still, analysing the timeline from the onset of symptoms provides a more accurate picture than merely presenting transfer logistics from the time of the emergency call placement or from the first contact with the tertiary centre the patient needs to be transferred to which is used in other publications on the topic. Our times of diagnosis (date and time on the first CT taken) and time of arrival at Neurosurgery are quite precise as we have strict routines to note the exact time a patient enters the emergency room at our hospital. We have not related our modes of transport to actual weather conditions that could have been decisive for the choice of transport medium. One may assume that the use of helicopter would have been even more frequent without days of fog and/or heavy winds. Furthermore, we had no data on availability of transport medium and if there were any delays in transport linked to this.

We measured the time from the onset of symptoms until arrival at a local hospital or Neurosurgery; however, we did

not account for any delay caused by the patients not seeking immediate medical attention. Some of the aneurysm rebleeds thus have to be attributed to patient delays and are not related to transport times or distances. Such an initial time delay has, however, not been found to be decisive for functional outcome or mortality [12], probably because it is mainly occurring in good-grade patients.

The number of rebleeds may be too low, because it may be difficult to detect a rebleeding in a sedated, intubated patient that has been transported directly to Neurosurgery.

The present study does not reveal the relationship of transport logistics to the in-neurosurgery rebleeds, timeline regarding aneurysm repair, cerebrospinal fluid diversion, length of intensive care and intensive care efforts as well as total length of stay at Neurosurgery. This relationship will be explored in a follow-up study.

Conclusions

Poor-grade aSAH patients have a high hourly frequency of aneurysm rebleed which is independent of the distance between the site of ictus and Neurosurgery. As rebleeding triples the chance of 1-year mortality, patients with GCS < 9 suspected to have suffered aSAH should be admitted directly to Neurosurgery without delay after best possible cardiovascular and airway optimisation on site by competent personnel.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required. Data retrieval has been approved by the institutional data protection officer.

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