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Original Research

Total Mission Time and Mortality in a Regional Interhospital Critical Care Transport System: A Retrospective Observational Study

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A B S T R A C T

Objective: We assessed the mortality risk related to the time for intensive care unit transport in a geographically large regional health care system.

Methods: Patient-level data from critical care ambulance missions were analyzed for 2,067 cases, mission time, and relevant patient factors. Mission time was used as a surrogate for the “distance” to tertiary care, and mortality at 7 days and other intervals was assessed.

Results: No increased mortality risk was found at 7 days in an unadjusted regression analysis (odds ratio = 1.00; range, 0.999–1.002; $P = .66$). In a secondary analysis, an increased mortality risk was observed in longer mission time subgroups and at later mortality assessment intervals (> 375 mission minutes and 90-day mortality; adjusted hazard ratio = 1.56; range, 1.07–2.28; $P = .02$). Negative changes in oxygenation and hemodynamic status and transport-related adverse events were associated with the longest flight times. Measurable but small changes during flight were noted for mean arterial pressure and oxygenation.

Conclusion: The main finding was that there was no overall difference in mortality risk based on mission time. We conclude that transport distances or accessibility to critical care in the tertiary care center in a geographically large but sparsely populated region is not clearly associated with mortality risk.

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With strong trends for regional centralization of tertiary health care resources, in sparsely populated and large geographic regions, this can mean dependence on air ambulance transport systems for access to critical care in tertiary hospitals. For longer distances between local hospitals and the regional tertiary care centers, there will be regular and systematic transferring of patients to the tertiary care centers. In the setting of acute critical illness and the need for definitive tertiary care, transport factors can reflect accessibility to the needed emergency critical care for those who live a long distance from the regional or national tertiary care center.

Distance traveled by air ambulance has been suggested to be associated with an increased risk of adverse events in flight as well as

affecting mortality.^{1–4} Furthermore, patients seem to be more frequently endotracheally intubated before transport in longer distances and tend to arrive at the destination hospital with a lower blood pressure.⁵ An increased risk of death has been reported after interhospital transportation,⁶ whereas other studies have not demonstrated this⁷ and rather attributed the risk to patient-level factors.⁸ Adverse events are also common in interhospital transportation, occurring in between 5% and 34% of all transports.^{1,2,9,10} Mechanical ventilation, hemodynamic instability, and fixed wing air ambulance rather than rotary wing has been suggested as predictors for in-flight critical events.¹ It is not known to what extent, if any, transport time contributes to mortality.

We hypothesized that a longer mission time (surrogate for a longer distance) would result in increased mortality when patient-level factors were taken into account. A secondary hypothesis was that oxygenation and hemodynamic status during transport were also associated with transport time and mortality.

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Methods

Ethical Statement

Ethical permission for the analysis of pseudoanonymized patient transport data was granted by the Swedish Ethical Review Authority (document number 2019-06525).

Setting

This cohort includes unplanned emergency intensive care cases transported by the regional fixed wing air ambulance system in northern Sweden from local hospitals and airports to the regional university hospital for definitive care (Figure 1). Unplanned in this context means that the referring hospital care team has initiated an emergency ambulance transfer mission through the national emergency response system as a transport over distance and beyond the means of that hospital and ambulance district to manage by themselves. This region's geographic area is approximately 25% larger than that of the New England region in the United States. The critical care air ambulance transports are staffed for both the ground and air transport segments by specialist anesthesiology and intensive care medicine physicians and nurses who have further air medical training, in addition to the usual air ambulance nurse who works only with the aircraft.

Study Design

Inclusion into the analysis was for all emergent adult intensive care fixed wing transports with the University Hospital of Umeå intensive care transport system during 2000 to 2016. The exclusion criteria were the following: transport solely for organ donation, no Swedish personal identity number, being under 16 years old at the time of transport, and nonurgent transport. Mission times, age, sex, physiological parameters such as mean arterial pressure (MAP), and ventilator settings such as fraction of inspired oxygen and positive end-expiratory pressure were included for analysis. Patients were grouped into 3 categories: trauma, surgical (nontrauma), or medical case types. Peripheral oxygen saturation was used instead of arterial blood gas because arterial blood gas data during transport were not available for most of the cases, and oxyhemoglobin percent tends to correspond well with arterial partial pressure of oxygen.¹¹

Primary and Secondary End Points

Mortality risk at 7 days after transport was chosen as the primary outcome to assess possible effects from the air ambulance intensive care unit transport events. Secondary outcomes included mortality at 24 hours, 30 days, and 90 days, with these later intervals included as common assessment points for intensive care patients. Secondary outcome analysis was planned for the relation of mission times to cofactors including age, sex, diagnostic group, and physiological parameters for oxygenation and circulatory instability.

Statistical Analysis and Data Handling

Chi-square testing was used for nominal data to show differences in proportions between groups. The Wilcoxon signed rank test was used to assess changes in continuous data that were not normally distributed. Logistical regression was used to test for a relation of total mission time from alarm to delivery in minutes to mortality outcome, including with relevant cofactors. Cox regression was used to assess the hazard ratio of mortality for nominal data (SPSS 26; IBM Corp, Armonk, NY). Differences in the mean in nonnormally distributed continuous variables was assessed using the Kruskal-Wallis H test. The total mission time was divided into mathematical quartiles. Adverse events reported in patient journals were subgrouped into transport related, patient deterioration, or a combination of the both. Transport-related events included waiting for ground ambulance, delays related to mechanical problems with the aircraft, or flight crew duty complications. Adjustments for the possible confounders,

including sex, age, and diagnostic group, were made in the Cox regression model. Complete case analysis was used.

Results

Study Population Enrollment

The whole cohort (N = 3,917) was screened, and 2,143 cases met the inclusion criteria (Figure 2). A further 76 cases were excluded for missing data on flight times, which left 2,067 cases for analysis.

Characteristics of the Cohort

The median age in our cohort was 61.1 years (Table 1), with the oldest patient being almost 96 years old. The majority of transported patients were men (64.3%), and the most common diagnostic group was surgical emergencies (40.8%). In almost all cases, a physician accompanied the patient. Adverse events occurred in 13.2% of cases, with the most common being patient deterioration (7.9%). The transport-related adverse events that were recorded included mission delay due to deviation from planned ground or air service (n = 54), problems with medical devices (n = 18), unplanned treatment need (n = 15), missing patient documentation (n = 12), and mission change due to hospital bed availability issue (n = 6). The cohort was divided into quartiles based on mission times to be able to compare exposure to shorter mission times compared with longer mission time exposures.

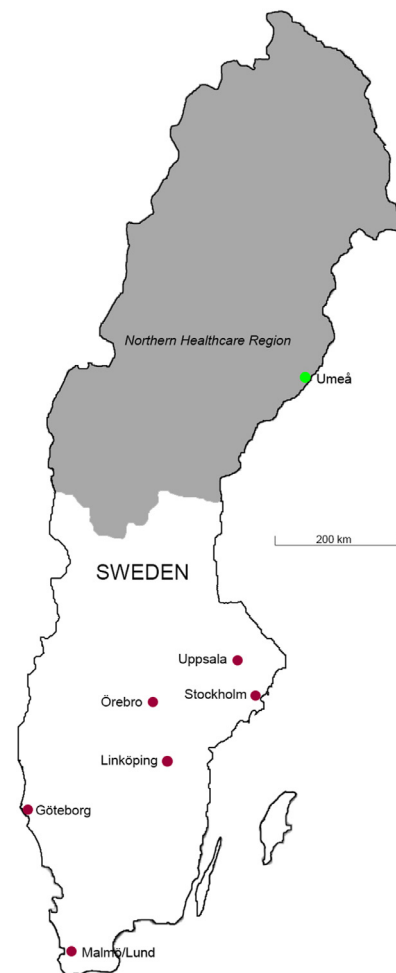


Figure 1. A map of Sweden. Tertiary hospitals are identified. The University Hospital of Umeå serves the whole Northern Healthcare Region.

Table 1
Characteristics of the Cohort (N = 2,143)

Age, median (range)	61.1 (16–95.6)
Male %	64.3
Diagnostic category, n (%)	
Surgical	874 (40.8)
Medical	472 (22.0)
Trauma	404 (18.9)
Other/not recorded	393 (18.3)
Physician onboard %	97.6
Adverse events, n (%)	
Patient deterioration	169 (7.9)
Transport related	106 (4.9)
Combination	7 (0.3)
No adverse event	1,861 (86.8)
Quartiles of total transport time, n (%)	
< 240	530 (24.7)
240–300	486 (22.7)
300–375	599 (28.0)
> 375	528 (24.6)
Missing	0 (0)
Total	2,143 (100)

Patient Characteristics According to Mission Time

Using chi-square tests, the transport time quartiles were assessed for association with level of oxygenation, circulatory disturbance, sedation, endotracheal intubation, diagnostic groups,

and adverse events. The lowest oxygenation category ($\text{SpO}_2/\text{FiO}_2 < 100$) was present in 2.8% of cases in the > 375-minute group, whereas this number was 0.4% in the < 240-minute group (Table 2). This trend was also seen in the other oxygenation groups (eg, 35.6% of the > 375-minute group having S/F 101–200, whereas the corresponding portion was 10.8% in the < 240-minute group). A mean MAP < 70 and/or noradrenaline infusion was found in 6.4% of cases for the < 240-minute quartile and in 24% of cases in the > 375-minute quartile. The same trend was observed with a higher number of sedated and endotracheally intubated cases in the longer mission time quartiles compared with the shorter time quartiles. Although more adverse events during flight were observed in longer mission time quartiles ($P < .001$, $df = 9$), when a subgroup analysis was performed, only transport-related adverse events were associated with mission time ($P = .011$, $df = 3$), whereas patient deterioration was not ($P = .471$, $df = 3$).

Mortality

The primary logistical analysis for mission time and mortality, in a univariate analysis, showed no association at the 7-day postmission assessment or any of the secondary time points (24 hours, 30 days, and 90 days), and this finding was confirmed in the multivariate analysis (Table 3).

Secondary analysis for all-cause mortality at 7 days posttransport, when comparing the longer mission time quartiles with the shortest,

Table 2
Transport Time Quartiles and Characteristics

	Total Transport Time (min)				Chi-Square Test
	< 240	240–300	300–375	> 375	
Oxygenation level ($\text{SpO}_2/\text{FiO}_2$)					$P < .001$, $df = 9$
< 100	2	3	5	15	
101–200	57	87	208	188	
201–300	33	26	35	41	
> 300	438	370	350	284	
Mean MAP < 70 or noradrenaline					$P < .001$, $df = 3$
Present	34	54	114	129	
Absent	493	431	484	398	
Sedation					$P < .001$, $df = 3$
Present	54	106	236	231	
Absent	472	379	357	292	
Endotracheal intubation					$P < .001$, $df = 3$
Present	51	99	221	209	
Absent	478	387	377	316	
Adverse events					$P < .001$, $df = 9$
Transport related	18	16	28	44	$P = .011$, $df = 3$
Patient deterioration	33	43	41	52	$P = .318$, $df = 3$
Combination	0	2	1	4	$P = .216$, $df = 3$
No adverse events	479	425	529	428	

Table 3
Mortality Risk and Cofactors

Univariate Logistical Regression				
Death within	Age	Sex	Diagnostic Group	Mission Time
24 h	1.013 (0.91–1.04, $P = .265$)	0.875 (0.423–1.813, $P = .720$)	0.66 (0.423–1.030, $P = .068$)	1.001 (0.999–1.003, $P = .285$)
7 d	1.021 (1.007–1.035, $P = .003$)	0.824 (0.541–1.254, $P = 0.366$)	0.752 (0.590–0.959, $P = .022$)	1.000 (0.999–1.001, $P = .981$)
30 d	1.032 (1.021–1.043, $P < .001$)	0.754 (0.554–1.027, $P = .073$)	0.836 (0.704–0.992, $P = .041$)	1.000 (0.999–1.001, $P = .738$)
90 d	1.035 (1.025–1.044, $P < .001$)	0.863 (0.656–1.136, $P = .295$)	0.861 (0.742–1.000, $P = .05$)	1.000 (0.999–1.001, $P = .984$)
Multivariate logistical regression				
24 h				
7 d	1.020 (1.006–1.034, $P = .005$)		0.779 (0.609–0.997, $P = .048$)	1.000 (0.999–1.002, $P = .658$)
30 d	1.032 (1.021–1.043, $P < .001$)		0.881 (0.740–1.050, $P = .158$)	1.001 (1.000–1.001, $P = .222$)
90 d	1.035 (1.025–1.045, $P < .001$)		0.913 (0.783–1.064, $P = .244$)	1.000 (1.000–1.001, $P = .291$)

Values are odds ratio (95% confidence interval, P value).

Table 4
Cox Regression of All-Cause Mortality Risk at Different Intervals and Mission Time (N = 2,067) Crude and adjusted for age and diagnostic group

Mission time (min)	24 h		7 d		30 d		90 d	
	HR Crude	HR Adjusted	HR Crude	HR Adjusted	HR Crude	HR Adjusted	HR Crude	HR Adjusted
< 240 (reference group)	—	—	—	—	—	—	—	—
240–300	1.64 (0.58–4.60, P = .350)	1.67 (0.59–4.69, P = .332)	1.09 (0.61–1.97, P = .767)	1.11 (0.62–2.02, P = .717)	1.12 (0.72–1.77, P = .612)	1.15 (0.73–1.82, P = .535)	1.21 (0.82–1.78, P = .336)	1.24 (0.84–1.83, P = .275)
300–375	1.33 (0.47–3.73, P = .591)	1.43 (0.51–4.02, P = .501)	1.21 (0.70–2.10, P = .491)	1.32 (0.76–2.30, P = .324)	1.52 (1.01–2.28, P = .043)	1.68 (1.12–2.53, P = .012)	1.45 (1.02–2.07, P = .040)	1.61 (1.12–2.30, P = .009)
> 375	1.17 (0.39–3.49, P = .777)	1.31 (0.44–3.95, P = .626)	0.96 (0.53–1.74, P = .889)	1.12 (0.61–2.05, P = .712)	1.20 (0.77–1.85, P = .425)	1.468 (0.95–2.28, P = .087)	1.26 (0.86–1.83, P = .235)	1.56 (1.07–2.28, P = .022)

HR = heart rate.

showed no difference in mortality risk when adjusted for age and diagnostic group at 24 hours or 7 days but a higher mortality risk at 30- and 90-days posttransport (Table 4).

Oxygenation and Circulatory Status

For all mission time quartiles, MAP decreased from takeoff to the lowest observed during transport, and there was even a measurable but small decrease when comparing takeoff and landing values (Table 5). For the S/F ratio, the lowest values during flight were lower compared with takeoff values, although there was a very small observed difference for the whole cohort.

Physiological parameters at arrival for the < 240-minute and > 375-minute groups showed that the S/F ratio, systolic blood pressure, and MAP were all lower in the > 375-minute group (Supplementary Table S1). There was no difference in heart rate (P = .251).

Age Differences

A Kruskal-Wallis H test was performed to study the age distribution in the different mission time groups (Supplementary Fig. S1). It was found that age was different between the quartiles (P < .001, df = 3), with a higher age found in the < 240-minute group (60.4 ± 1.3) and a lower age in the > 375-minute group (52.6 ± 1.6).

Discussion

The main finding was that there was no increase observed in mortality risk related to mission time at the primary assessment point, 7 days, or at any of the intervals up to 90 days. Secondary findings showed that there was an increased adjusted hazard ratio for all-cause mortality at 30 and 90 days for longer transport times but not for the assessment intervals shorter than 30 days. These findings are demonstrated in a mixed trauma, surgical, and medical cohort where there was emergency transport to the tertiary center as indication. Secondary findings were purely exploratory and may support a possible higher likelihood of minor negative physiological changes and increased interventions with longer mission times. Adverse events related to transport factors were also increased in longer mission times. However, adverse events with patient deterioration were not increased. Paradoxically, the longer mission time quartile had a lower age. This study is based on a unique cohort from the geographically large and sparsely populated area in northern Sweden where the public health care system (which includes the air ambulance) allows complete follow-up for mortality. These findings support the interpretation that mission time by itself, in the context of acute long-distance intensive care transport to definitive care, is not associated with an increased risk for mortality when analyzing the whole cohort. Secondary findings indicate a possible increased risk for those with physiological derangements and longer mission times.

These findings in an acute critical care cohort are in line with previously published reports that have suggested no increased mortality in patients transported up to 800 miles by fixed wing air ambulance⁴ and no difference in transport time between survivors and nonsurvivors in an intensive care unit cohort,¹² whereas other studies points to an increased risk of mortality.³

Some clinical factors may interact with longer transport times. Some tertiary care categories may have a higher likelihood of need for intubation and sedation. Deep sedation can affect circulatory parameters but may be necessary when patients have severe oxygenation problems.¹³

There was no indication in this cohort of clinically relevant patient deterioration during flight regardless of transport time. There are previous reports of increasing numbers of critical events in fixed wing air ambulance with longer distances traveled.¹ Transport-related technical/mechanical problems in this cohort were few compared with other reports from road-based mobile intensive care units¹⁴ and even compared with intrahospital transports.¹⁵ Minor changes of unclear clinical

Table 5
Physiological Changes During Flight

	Mean Difference Between Takeoff to Lowest During Flight			Mean Difference Between Takeoff and Landing		
Time (min)	< 240	> 375	Whole Cohort	< 240	> 375	Whole Cohort
MAP (n = 1,347)	−5.2 (P < .001)	−5.7 (P < .001)	−5.4 (P < .001)	−2.0 (P = .005)	+0.3 (P = .288)	−1.3 (P = .002)
S/F ratio (n = 2,094)	−3.2 (P < .001)	−4.0 (P < .001)	−3.6 (P = .075)	−0.3 (P = .655)	+1.1 (P = .969)	−5.1 (P = .643)

MAP = mean arterial pressure; S/F = SpO₂/FiO₂.

P value determined using the Wilcoxon-signed rank test.

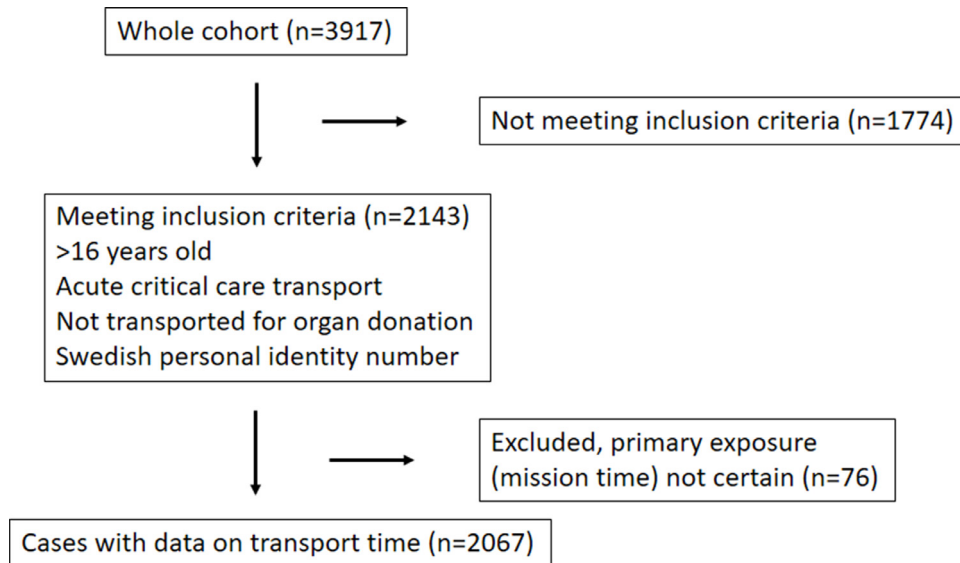


Figure 2. A flowchart for case selection.

significance in the S/F ratio and MAP during transport were found and were similar to those reported in previous studies.⁵ A study from Finland of road ambulance critical care transports found no difference in heart rate, systolic blood pressure, or MAP, but a decrease in PaO₂/fraction of inspired oxygen ratio of −2 mm Hg was found,¹⁶ which is similar to what was observed in this cohort in the < 240-minute quartile (Table 4). Other studies have shown no change or increase in the PaO₂/fraction of inspired oxygen ratio during or after interhospital transport.⁹ The risk for respiratory deterioration during transport of critically ill patients is well recognized.¹⁷

A lower age in the longer mission time quartile was observed, but local decisions to withhold transfer because of advanced age and comorbidity could potentially contribute to this, as previously observed in a rotary wing retrospective cohort.⁵ There is always a decision-making balance between perceived gains versus futility when considering transfer from a local hospital to a tertiary care center, although no data to assess this were available for analysis in this cohort.

The major limitation of our study is the lack of data on comorbidity or disease severity before transport, which means that bias for these factors could influence the results. This cohort was mixed for critical care intensity, with less than half intubated and mechanically ventilated or treated with a potent vasopressor during transport. Furthermore, the referral patterns for this specific region and cohort could differ from other regions, traditions, and preferences. This database is dependent on accuracy in patient transport record keeping, which is a recognized source of some error in assessing patient status.

Conclusion

In summary, the main finding was no overall clear relation between mission time and mortality risk. We conclude that transport

distances or accessibility to critical care in a tertiary care center in a geographically large but sparsely populated region is not clearly associated with mortality risk.

Supplementary materials


Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.amj.2021.08.005>.

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