Stroke

CLINICAL AND POPULATION SCIENCES

Cost-Effectiveness of Mobile Stroke Unit Care in Norway

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BACKGROUND: Acute ischemic stroke treatment in mobile stroke units (MSUs) reduces time-to-treatment and increases thrombolytic rates, but implementation requires substantial investments. We wanted to explore the cost-effectiveness of MSU care incorporating novel efficacy data from the Norwegian MSU study, Treat-NASPP (the Norwegian Acute Stroke Prehospital Project).

METHODS: We developed a Markov model linking improvements in time-to-treatment and thrombolytic rates delivered by treatment in an MSU to functional outcomes for the patients in a lifetime perspective. We estimated incremental costs, health benefits, and cost-effectiveness of MSU care as compared with conventional care. In addition, we estimated a minimal MSU utilization level for the intervention to be cost-effective in the publicly funded health care system in Norway.

RESULTS: MSU care was associated with an expected quality-adjusted life-year-gain of 0.065 per patient, compared with standard care. Our analysis suggests that about 260 patients with ischemic stroke need to be treated with MSU annually to result in an incremental cost-effectiveness ratio of about NOK385 000 (US$43 780) per quality-adjusted life-year for MSU compared with standard care. The incremental cost-effectiveness ratio varies between some NOK1 000 000 (US$113 700) per quality-adjusted life-year if an MSU treats 100 patients per year and to about NOK340 000 (US$38 660) per quality-adjusted life-year if 300 patients with acute ischemic stroke are treated.

CONCLUSIONS: MSU care in Norwegian settings is potentially cost-effective compared with conventional care, but this depends on a relatively high annual number of treated patients with acute ischemic stroke per vehicle. These results provide important information for MSU implementation in government-funded health care systems.

GRAPHIC ABSTRACT: A graphic abstract is available for this article.

Key Words: ischemic stroke ■ repefusion ■ thrombectomy ■ time-to-treatment ■ triage

Stroke is the second leading mortality cause in most Western countries, and a major cause of adult disability.[1] Stroke accounts for considerable consumption of health care resources and has substantial economic consequences for patients, relatives, and society.[2] In Norway, >10 000 persons experience acute stroke each year, of which about 85% are ischemic stroke.[3] In acute ischemic stroke (AIS), treatment with thrombolysis and thrombectomy are recommended within defined time windows where earlier treatment leads to better outcomes.[4,5] The first hour after symptom onset, the golden hour, is the time span when reperfusion treatment most effectively can increase the chance of a good outcome.[6,7]

Mobile stroke units (MSUs) is a novel approach aiming to reduce the onset-to-treatment time by enabling

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Nonstandard Abbreviations and Acronyms

AIS	acute ischemic stroke
IVT	intravenous thrombolysis
mRS	modified Rankin Scale
MSU	mobile stroke unit
NASPP	the Norwegian Acute Stroke Prehospital Project
NOK	Norwegian kroner
QALY	quality-adjusted life-year
WTP	willingness to pay

diagnostics and thrombolytic treatment already in the prehospital phase.[8] An MSU is an ambulance equipped with a computed tomography scanner, a point-of-care laboratory and a stroke team that diagnose, triage, and provide prehospital treatment of stroke.[9,10] MSU care is found to reduce time to intravenous thrombolysis (IVT), increase both the thrombolytic and golden hour rate and improve outcomes patients with ischemic stroke.[9,11,12] MSU treatment is also shown to be safe and does not increase hemorrhagic complications or mortality.[9,11,12]

Recently published results from the Norwegian Treat-NASPP trial (the Norwegian Acute Stroke Prehospital Project) found that integrating thrombolysis of AIS in the physician-based emergency medical services reduces time-to-treatment and increases both thrombolytic and golden hour rates.[13]

Introducing MSU as standard care represents substantial investments in infrastructure, training, and operational costs, and the cost-effectiveness of this needs to be investigated before implementation. Globally, few economic evaluations have considered the implementation of MSU.[14–16] For Norway, the feasibility of a Norwegian MSU in the prehospital setting has been confirmed,[13,17–19] and its cost-effectiveness explored in a health technology assessment.[20] The health technology assessment was based on the efficacy data from the MSU study in Berlin,[21] and the validity of the cost-effectiveness results in a Norwegian setting is therefore uncertain. The objective of this article was therefore to expand on the generalizability related to cost-effectiveness of MSUs by revisiting the cost-effectiveness of the Norwegian MSU and incorporating the efficacy data from Treat-NASPP.

METHODS

The present article is reported according to the Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022),[22] completed checklist is available in the Supplemental Material. Data supporting these analyses are available from the corresponding author on reasonable request.

Decision Analytical Model

We built a combined decision tree and discrete time model (Markov) and used it to estimate incremental costs, incremental health benefits, and incremental cost-effectiveness of introducing treatment of patients with stroke with MSU, compared with current standard of care (standard ambulance and in-hospital care) in Norway. In any given area with an implemented MSU, some proportion of patients with AIS will continue to receive standard treatment depending on availability of the MSU and for other logistical reasons. MSU operations involve significant fixed costs, which means that a reasonably high number of patients is necessary to bring down average cost per treatment to acceptable levels. The model contains efficacy data from a Norwegian MSU trial,[13] while real-life implementation data for service utilization are unavailable. We therefore conducted a threshold analysis to estimate the utilization rate that would be needed for implementation of MSU to be cost-effective.

The Markov model captures long-term costs and consequences and was adopted and further developed from a previously published model[20] and is based on 3 health states defined by the modified Rankin Scale (mRS) used to classify degree of disability or dependence in poststroke patients[23] (Figure S1):

- "Independent" (mRS score 0–2). Patients with this health state can be assumed to be self-reliant in daily activities
- "Dependent" (mRS score 3–5), entails that the patient requires external help and/or relies on health care services
- "Dead" is an absorbing state.

We applied a cycle length of 1 year. At the end of each cycle, the model evaluated how the cohort of patients had moved between the health states during the previous year, based on transition probabilities. The transition probabilities could vary with current health state and age. Depending on transition probabilities, patients could after the completion of a cycle remain in the same state or transit to another state. Transition from the "dependent" to "independent" state was assumed to only be possible through rehabilitation and spontaneous regression of neurological outcomes within the first year after stroke[24] modeled using a tunnel function. A decision tree was used to capture short-term events, and a complete overview of the model structure is given in Figure S2 in the Supplemental Material. We let the model run for 25 annual cycles, after which most of the patients were dead. All costs and health outcomes were discounted using a rate of 4%.

Population and Interventions

We assumed that patients with acute ischemic stroke receiving IVT were 70 years initially, corresponding to the patient's characteristics from Berlin.[21] We compared 2 diagnosis and treatment options for patients with acute ischemic stroke: (1) IVT delivered through MSU care. This option encompasses all patients transported by MSU, regardless of whether IVT was ultimately given in the MSU or in the hospital (according to an intention-to-treat approach). 2) Standard ischemic stroke care, that is, transport with conventional ambulance followed by in-hospital diagnosis and IVT treatment.

The MSU used in the Norwegian clinical trial was an ambulance equipped with a computed tomography scanner and a point-of-care laboratory.[13] The MSU was staffed with an anesthesiologist trained in prehospital critical care, a paramedic nurse and a paramedic, and the team were equipped with a standardized treatment protocol. We assumed that the MSU would be introduced alongside conventional ambulances. There are important diurnal variations in stroke dispatch where almost 90% of stroke transportations in the emergency medical services occurs between 7 AM and 11 PM.[25] The Norwegian MSU was operative for 12-hour shifts (8 AM to 8 PM), and this time setup is similar to other MSUs worldwide.[11–13,26]

Clinical Efficacy

We base our assumptions about efficacy on the results from Treat-NASPP,[13] which show that in 440 participants the MSU led to significant reductions in time from symptom onset-to-treatment for patients with AIS as well as higher thrombolytic rates.

Median onset-to-treatment time was an absolute 17 minutes shorter in the MSU group compared with the standard care group (101 versus 118 minutes). The thrombolytic rate was 81% in the MSU group compared with 59% in the control group (P=0.001).[13] Ultraearly thrombolysis defined as IVT≤60 minutes after symptom onset, the "golden hour", was 4.1 times higher with MSU compared with conventional ambulances (15.2% versus 3.7%, P=0.005). In the clinical trial, the MSU was not permitted to enroll patients situated <10 minutes driving distance from the hospital. Our model was therefore based on a secondary analysis where this 10-minute radius was employed also in the control group, showing a 13-fold higher golden hour rate for MSU patients compared with the controls (15.2% versus 1.2%; P=0.001). There were no significant differences in serious adverse events or symptomatic intracranial hemorrhages between the groups, and adverse events were therefore not modeled.

To translate these outcomes into relevant long-term health outcomes, we combined golden hour and thrombolytic rates from the Treat-NASPP study with the results of the SITS-EAST registry study[27] and the pooled analysis of ATLANTIS, ECASS, and NINDS rt-PA stroke trials.[28] The SITS-EAST study compares functional outcomes of patients with AIS who received IVT within and outside the golden hour. The results show reduced mortality and clearly better outcomes measured on mRS at 90 days for patients treated within the golden hour (Table 1). State mRS score 0 to 2 is the best health outcome, where patients are independent. For mRS score 3 to 5, patients require care from health services, while mRS score 6 represents death. The last column of Table 1 shows outcomes for eligible patients with AIS who did not receive IVT.[28]

Table 1. Distribution of mRS Score at 90 Days for Patients Treated Within, Outside the Golden Hour, and Not Treated With IVT

mRS score	Patients treated outside the golden hour, %	Patients treated inside the golden hour, %	Patients with AIS not treated with IVT
mRS score 0–2	53.6%	59.2%	41.3%
mRS score 3–5	33.7%	32.4%	44.2%
mRS score 6	12.7%	8.4%	14.5%

Source: derived from Tsivgoulis et al[27] and Hacke et al.[28] AIS indicates acute ischemic stroke; IVT, intravenous thrombolysis; and mRS, modified Rankin Scale.

Transition Probabilities and Utility Values

In Table 2, we present variables used to inform the transition probabilities used in the model, as well as health state utilities used to calculate quality-adjusted life years (QALYs). We modeled mortality separately for 3 different time periods: 0 to 90 days, 90 to 365 days, and beyond 1 year. Annual mortality rates beyond 1 year are based on all-cause age-dependent mortality rates from a Norwegian life table,[31] multiplied with hazard ratios depending on mRS-status. This assumes that stroke patients have an increased risk of death compared with the general population. Assumptions about mortality during recurrent stroke (0–90 days) and between 90 and 365 days were based on data from Norwegian Patient Registry.[30]

Costs of Mobile Stroke Unit

Costs were considered from the perspective of national health services in Norway, while costs for patients, families, and other stakeholders were disregarded. This is in accordance with guidelines for health economic evaluations in Norway.[32] We estimate that the total annual cost for 1 MSU will be ≈ 6.6 million Norwegian kroner (NOK) (US$750 400), based on data from the Treat-NASPP study.[33] We divided the costs into the following 3 categories: (1) operational costs, (2) personnel costs, and (3) cost of medical devices (Table S1). The costs do not include value added tax. The operational costs for 1 MSU include annual capital costs on the vehicle (depreciation plus opportunity cost of the investment), insurance, annual fee, service agreements, parking, fuel, and variable maintenance. The medical device post includes depreciation costs on the investment, telemedicine (including tele-stroke assessment and tele-radiology), tablet, service agreement for computed tomography scanner, and medical equipment follow-up. Personnel costs include employment costs of an MSU-team: 1 physician (an anesthesiologist trained in prehospital critical care, 1 100 000 NOK annual salary rate or NOK 2 501 053 per year per MSU with 12-hour shifts [US$284 370]), and ambulance crew, including paramedic nurse and paramedic, costing 6800 NOK per 12-hour shift or a total of NOK 2 448 000 per year per MSU (US$278 340; Table S1). The personnel cost estimate presumes 360 operating days annually, 12 hours daily. This cost was adjusted from trial data to a more realistic scenario based on advice from experts.[33] We depreciated relevant medical equipment/devices over a period of 9 years.

Unit Costs and Threshold Analysis

We calculated unit costs per transportation with an MSU by dividing the total cost of about 6.6 million NOK (US$750 400) with the anticipated number of patients receiving this service. Since the latter is unknown, we explored the impact of a range of utilization levels in a threshold sensitivity analysis. We assume that utilization in Norway is likely to be in the range between 100 (pessimistic) and 300 (optimistic) transportations and administrations of IVT per MSU per year, which translates to unit costs per patient treated with MSU ranging between NOK65 770 (US$7478) and NOK21 924 (US$2493). To perform deterministic and probabilistic sensitivity analyses, we assumed a base case scenario in which an MSU treats 180 patients per year.

Table 2. Probabilities and Risk Information Used to Control Transitions Between Health States and State Utilities (QALY-Values)

Parameter	Value (SE)	Range	Source
Hazard ratio of death beyond 1 y for independent patients (mRS score 0–2)*	1.04 (0.08)	(0.89–1.30)	Based on hazard ratios used in Leppert et al[29]
Hazard ratio of death beyond 1 y for dependent patients (mRS score 3–5)*	1.78 (0.46)	(1.02–2.84)	Based on hazard ratios used in Leppert et al[29]
Risk of recurrent stroke	0.05 (0.01)	(0.036–0.067)	[24]
Mortality when recurrent stroke (0–90 d)	0.19 (0.03)	(0.152–0.228)	[29]
Mortality between 90 and 365 d	0.07 (0.01)	(0.05–0.09)	Norwegian Patient Registry[30]
Transition from dependent to independent (only first year)	0.11 (0.02)	(0.078–0.144)	Recalculated from Ganesalingam et al[24]
Probability of being independent after surviving a stroke	0.50	(0.35–0.65)	Assumption
Utility for patient in independent state (mRS score 0–2)	0.74 (0.02)	(0.70–0.77)	Ganesalingam et al[24]
Utility for patient in dependent state (mRS score 3–5)	0.38 (0.05)	(0.29–0.47)	Ganesalingam et al[24]
Age in years of patients entering the model	70	(68–74)	Kunz et al[3]

mRS indicates modified Rankin Scale; and QALY, quality-adjusted life-year.
*Mortality after 365 d: lifetables×hazard ratios.

Other Costs

We assumed that the unit cost per patient transported by a conventional ambulance is NOK3 921 (US$446), based on cost estimates from the greater Oslo area.[34]

The diagnostic-related groups-derived estimates are compound and include the whole hospitalization-period, and the cost of administering the maximum dose of tPA (tissue-type plasminogen activator), which does not exceed 10 000 kroner (US$1137).[33] Based on the diagnostic-related groups code 14A,[35] we estimated the cost of treating a patient with AIS with IVT equals NOK91 195 (US$10 369). We assumed that the IVT cost will be the same for patients receiving MSU and standard care, thus the cost of treating patients with AIS who does not receive IVT equals 81 195 kroner (US$9232). In the absence of Norwegian estimates for overall costs associated with long-term follow-up, rehabilitation, secondary follow-up, nursing and care for patients who have undergone stroke, we used Swedish cost data.[36] These costs are comparable to Norwegian settings due to the similar health care systems and reflect average costs for specialist- and municipal health services. We differentiated these health state costs between costs incurred in the first year of stroke treatment and costs that accrue annually after the first year. The costs vary according to the patient's functional level, and in the model they are recorded and cumulated for each health state at the end of each cycle (Table S2).

Sensitivity Analyses

To explore overall decision uncertainty, we performed a probabilistic sensitivity analysis with 10 000 iterations based on distributions for input variables for base case scenario. We used gamma distributions for cost parameters, beta distributions for probabilities, log-normal distributions for hazard ratios, and Dirichlet distributions for multivariate parameters.

We also performed a series of 1-way sensitivity analyses for the key-parameters to explore the influence of uncertainties in individual parameters on model outcomes and presented the results in a tornado diagram (Figure S3). Information about the ranges used are given in Table 2 and Table S2.

RESULTS

Threshold Analysis

Our results show that as the number of patients that receive IVT through MSU care increases, the incremental cost per QALY decreases and the intervention becomes more attractive in terms of cost-effectiveness. If more than about 260 patients with ischemic stroke were treated per MSU annually, it would result in an incremental cost-effectiveness ratio of less than about NOK385 000 (US$43 780) per QALY for MSU compared with standard care. We assume that NOK385 000 (US$43 780) is a realistic willingness to pay threshold for AIS treatment, after adjusting for disease severity level and according to a suggestion from a Norwegian commission on health care priority setting.[37] The same commission on priority setting indicates a maximum willingness to pay (WTP) of about 825 000 NOK (US$93 800) per QALY for the conditions considered to be most severe[37], and our results indicate that this level would be achieved when 125 patients with AIS are treated annually per MSU (Figure 1).

Cost-Effectiveness Results With an Assumption of 180 Patients With AIS Annually

The health economic model estimates an expected incremental QALY-gain of 0.065 per patient who receives treatment with thrombolysis through MSU care, compared with standard care (Table 3). The expected incremental costs per patient receiving thrombolysis through MSU care, compared with conventional care depends on the number of patients treated annually with MSU. Assuming 180 patients treated with IVT through MSU annually, the total costs per patient over the lifetime horizon accumulates to NOK690 514 (US$78 510), most of which are costs of rehabilitation. In comparison, the lifetime cost per patient with conventional ambulance is NOK653 951 (US$74 350). The incremental costs sum up to NOK36 563 (US$4157) per patient, compared with standard care, yielding an incremental cost-effectiveness ratio of about NOK560 020 (US$63 670) per QALY (Table 3).

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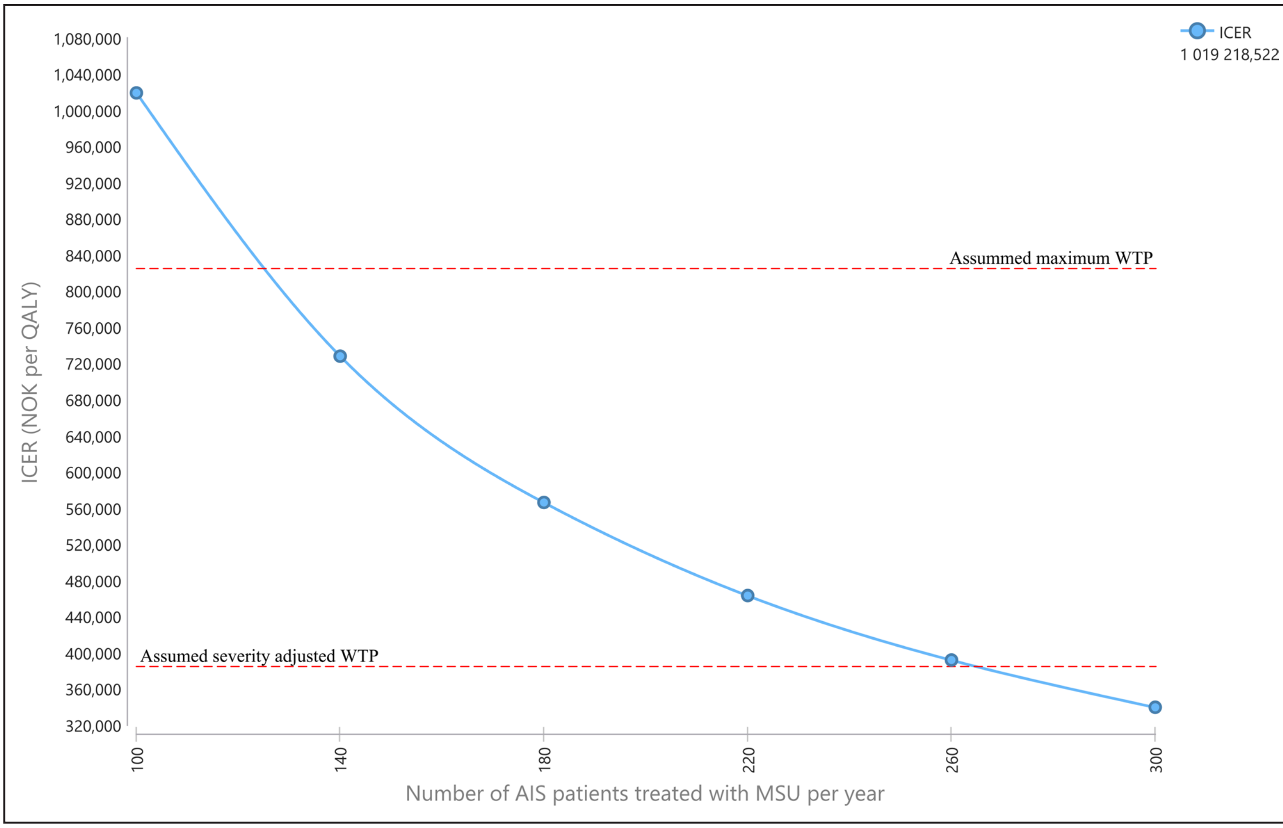

Figure 1. One-way cost-effectiveness sensitivity analysis showing how the incremental cost-effectiveness ratio (ICER) for mobile stroke unit (MSU) compared with standard ambulance depend on the annual number of patients served by 1 MSU.
The lower dotted line represents the assumed willingness to pay (WTP) per quality-adjusted life-year (QALY) in Norway when the severity of acute ischemic stroke (AIS) is taken into account. The upper dotted line represents the assumed maximum WTP in Norway for conditions assumed to be most severe.

In Figure 2A, we present the results of the probabilistic sensitivity analysis performed with an assumption of 180 patients with AIS treated annually by 1 MSU. The dots represent incremental cost and effectiveness pairs of MSU compared with the conventional care from the 10 000 iterations of the Monte Carlo simulation. Green color indicates observations that are cost-effective, while red dots are not, assuming that the maximum WTP for 1 QALY is NOK385 000 (US$43 780). At this WTP, the proportion of iterations that were cost-effective was 15.5%.

The cost-effectiveness acceptability curve (Figure 2B) indicates that MSU has higher probability of being cost-effective than standard ambulance when the WTP exceeds NOK560 020 (US$63 670) per QALY. As WTP increased, the probability of the MSU being cost-effective also gradually increased. One-way sensitivity analyses are illustrated using a Tornado diagram and show that the incremental cost-effectiveness ratio is most sensitive to variation in the cost of thrombolysis. The incremental cost-effectiveness ratio also becomes more favorable if the outcomes are not discounted (Figure S3). The average age of patients experiencing an AIS is also somewhat influential.

DISCUSSION

MSUs are operative in several countries worldwide, but there is still little evidence on cost-effectiveness, and most MSUs rely on sponsors and funding.[10] This is the first economic evaluation that considers cost-effectiveness of MSU care compared with standard care in a government-funded health care system. We estimated that MSU care will give an incremental health gain per patient of 0.065 QALY with an incremental cost-effectiveness ratio of NOK560 020 (US$63 670) per QALY assuming that 180 patients are treated annually.

Our results show that in the short run the costs for the specialist health services are expected to increase due to the cost of the MSU, and because of a higher proportion of patients reaching the required time window and receiving IVT. In the longer term, some of these increased costs will be offset by reduced costs of rehabilitation and long-term care, especially in the community health services, with relatively modest incremental lifetime costs of NOK36 563(US$4157) per patient. The health gains of 0.065 QALYs are generated both by the reduction in time to IVT and the increased thrombolytic rate. These improvements translate into enhanced functional outcomes for the patients with AIS (Figure S4A through S4C).

Table 3. Cost-Effectiveness Results With Assumption of 180 Patients Treated With MSU

	Total costs in NOK (US$)	Effects (QALYs)	Incremental cost in NOK (US$)	Incremental effect (QALYs)	Incremental cost-effectiveness ratio (NOK/QALY) (US$/QALY)
Standard ambulance	653 951 (74 350)	6.063			
MSU	690 514 (78 510)	6.128	36 563 (4157)	0.065	560 020 (63 670)

MSU indicates mobile stroke unit; NOK, Norwegian kroner; and QALY, quality-adjusted life-year.

We combined efficacy data from 3 studies to obtain the transition probabilities in our model: (1) Treat-NASPP demonstrated that MSU care leads to both increased thrombolytic rate and increased golden hour rate compared with standard care; (2) SITS EAST registry data were used to model functional outcomes for patients with AIS who received IVT within and outside the golden hour,[27] and (3) a pooled analysis of stroke studies to model outcomes for patients with AIS who do not receive IVT.[28] In sum, the model leans on the assumptions that reductions in time to treatment translate into health gains and improved prognosis for the patients. The direct association between the use of MSU and improved functional outcomes for patients with AIS has recently been demonstrated.[11,12] The exact impact of the introduction of an MSU in specific settings will depend upon many factors, including geography, population density, local emergency medical services protocols, hospital relationships, infrastructure, and climate. Depending on where the patient is located geographically, different logistic options and challenges will be present. While introduction of MSU is not feasible in all areas due to few annual patients, several cities and areas in Norway are candidates for mobile stroke unit care according to the population density and annually reported number of thrombolyzed patients.[3] The thrombolysis rate will also increase with the utilization of a mobile stroke unit, as shown in the Norwegian study where an absolute increase of 22% was reported.[13] Our results have validity for urban and suburban areas in other Nordic countries with similar health care structure and to other countries with publicly funded health care systems. Rural areas in Norway are characterized by particularly long distances and low population densities, the use of air ambulance is essential for providing these services and may be used independently, or in cooperation with MSU care. An MSU staffed with a physician-based emergency medical services team consisting of prehospital critical care personnel is advantageous in less populated areas where there are fewer stroke dispatches, as the model may function as a medical emergency unit and also be dispatched to other medical and traumatic emergencies.[38]

In Norway, a health policy goal is equal access to health care, both emergency and specialized treatment, for the entire population regardless of residency. But still, fewer than half of the patients with AIS in Norway reach the time window for IVT.[3] The main reason for missing the narrow time window is that the patients arrive at the hospital too late. The time factor covers both time from symptom onset to alarm (patient delay) and time from alarm to treatment, including transportation time and logistics (transportation- and logistics delay). The largest delay is often caused by late alarm, which is beyond the control of the emergency services.[39] Treat-NASPP demonstrates that many of the late-presenting patients could be treated within the time window due to reduced onset-to-treatment time resulting from MSU care, but the size of this effect is unknown and outside the context of this trial. MSUs may have great potential in both urban and rural settings, but it is difficult to evaluate how including remote and sparsely populated areas in our analysis would affect the results. Patients in regions with long travel times may benefit even more from time saving than those in urban areas, with potentially higher health gains per patient. However, in areas where the absolute stroke incidence is low and few patients may utilize the MSU, the per-patient costs of the intervention would be substantially higher, as demonstrated by our threshold analysis.

We used a probabilistic Markov model, which is considered the appropriate approach to simulate the natural history of stroke. This economic model was previously used in high-quality health technology assessment reports.[20,34] Further, we have updated the model using data sources that are relevant for a Norwegian setting and based on Norwegian clinical practice.

Our model compares MSU care with standard care, with an underlying assumption that the 2 are mutually exclusive. While this is clearly the case at the individual patient level, the assumption of mutual exclusiveness is not feasible at a population level. In each catchment area, the 2 modes of transportation and treatment will work in parallel, and the choice between an MSU and a regular ambulance will depend on intensity and specificity of symptoms, availability, distance and other factors. The Norwegian study was conducted in a nonurban area where 86% of the MSU dispatches were rendezvous,[13] meaning that parallel dispatch was necessary to reduce prehospital delay. The study also showed that around 40% of the stroke code dispatches were for nonstroke patients, meaning that many of these patients are not in need of MSU care and that the conventional ambulance will be involved in the patient assessment. In our model, these aspects were captured and controlled by the key parameter “number of patients who receive thrombolysis through MSU care”. In both pre- and in-hospital settings, there will be stroke mimics among the IVT-treated patients as this patient group is a natural part of acute stroke evaluations. Reports from previous MSU studies have shown that MSU care does not increase the proportion of stroke mimics treated with IVT as compared

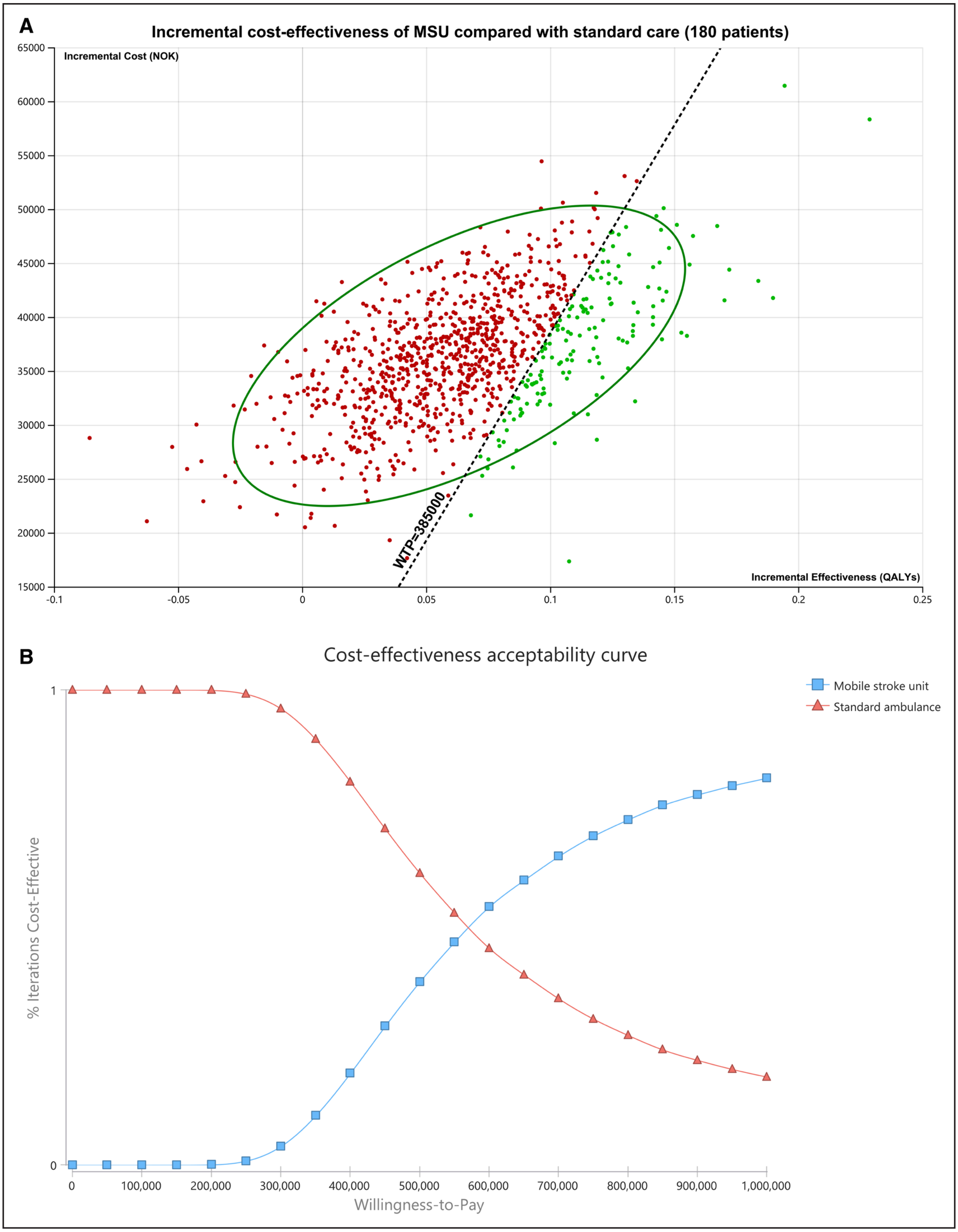

Figure 2. Results of probabilistic cost-effectiveness analysis comparing mobile stroke unit (MSU) with standard care, based on an assumption of 180 patients with acute ischemic stroke (AIS) treated annually.

A, Scatter plot with incremental cost-effectiveness following a simulation with 10 000 iterations. The diagonal line illustrates a willingness to pay (WTP) of NOK385 000 (US$43 780) per quality-adjusted life-year (QALY). Green color indicates observations that were cost-effective at this WTP (15.5%), and red color indicates observations that were not. **B**, Cost-effectiveness acceptability curve for a range of WTP per QALY.

with conventional management,[12,40] meaning that MSU care does not increase costs related to treatment of nonstroke patients.

Limitations

We conducted the analysis from a health care provider perspective, but stroke has high health-related and economic consequences also for the patients and the society in a broader sense. The societal costs will most likely increase in the coming years as a result of the changed age composition in the population. The costs for an MSU was based on Norwegian data,[33] adjusted from a trial situation to a more realistic scale up scenario. Since the intervention has not yet actually been routinely implemented in Norway, and since there are unclarities regarding the organization setup, there are still some uncertainties around the estimates. In addition, unit prices which amount to the total MSU cost could be negotiated in a potential introduction, adding to the uncertainty. We assumed that the MSUs, as well as all personnel, would come in addition to existing standard ambulances. In practice, when integrating MSUs into routine practice there might be scope for some resource sharing and economies of scale. Finally, we have used diagnostic-related groups code 14A as cost of IVT in both the intervention and comparator arms. This approach may double count some cost items in the MSU arm, and in this sense our estimates in favor of MSU are conservative.

Our model did not explicitly consider routes other than MSU and conventional ambulance for coming to hospital (ie, physician referral, inpatient, walk into emergency department, and transfer from other hospitals). Also, we did not account for the possibility that MSU care could lead to better resource utilization by reducing unnecessary transportation, and unnecessary admissions and examinations in the hospital,[41] Further, we did not assess treatment and triage of hemorrhagic stroke, traumatic brain injury or patients with large vessel occlusions due to the lack of data, and the absence of endovascular treatment data in the model is a major limitation. However, data from Treat-NASPP indicate that the MSU model increases the proportion of both LVO and ICH patients transported to a CSC,[13] which suggest that prehospital triage can significantly reduce time to specialized treatment and improve outcomes for these patients.[42,43] In sum, these unaccounted factors indicate that our cost-effectiveness considerations are conservative.

The linear association between onset-to-treatment time and stroke outcomes is not addressed in our article.

It must be emphasized that prehospital computed tomography represents a supplementary tool to increase efficiency of stroke management and not intended to replace other efforts to improve pre- and in-hospital stroke management.

Conclusions

MSU care in a Norwegian setting is potentially cost-effective compared with conventional care but this depends on a relatively high annual number of treated AIS patients per vehicle. This provides important information regarding MSU implementation in government funded health care systems.

ARTICLE INFORMATION

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Disclosures

None.

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