Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eMethods 1. Data use acknowledgements

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eMethods 2. Fatal crash probability

For helicopter transport the rate of fatal crashes per 100,000 flight hours from 2000 to 2005[1] (Table 1) was averaged giving a fatal accident rate of 1.8833 fatal crashes per 100,000 flight hours. To convert flight hours to miles traveled, an average flight speed of 120 miles per hour was multiplied by 100,000 flight hours to give 12,000,000 miles traveled as the equivalent of 100,000 flight hours. The averaged fatal accident rate of 1.8833 was then divided by 12,000,000 miles to obtain the fatal crash rate per mile traveled of 0.0000001569, or 1.6×10^{-7}. This fatal crash rate was then multiplied by the transport distance to obtain the probability of a fatal crash for any given helicopter transport. This results in a probability of 8.6×10^{-6} for fatal crash in the base-case of a 55mile helicopter transport.

Table 1. Fatal medical helicopter crash rates per 100,000 flight hours

Year	2000	2001	2002	2003	2004	2005
Fatal crash rate (per 100,000 flight hours)	2.1	1.8	2.1	1.5	2.0	1.8

For ground ambulance transport, a rate of 7.7 fatal crashes per 100,000,000 miles traveled has been reported, although may vary widely given the absence of systematic collection of ambulance fatal crash data.[2] This was converted a fatal crash rate of 0.000000077 per mile traveled, or 0.8×10^{-7}. This fatal crash rate was then multiplied by the transport distance to obtain the probability of a fatal crash for any given ground ambulance transport. This results in a probability of 4.2×10^{-6} for fatal crash in the base-case of a 55mile ground ambulance transport.

eMethods 3. Risk adjustment models and conversion of adjusted odds ratios to probability of survival

To determine the probability of survival for patients transported by helicopter emergency medical services (HEMS) under the current triage strategy, a risk-adjusted odds ratio for survival of HEMS compared to ground emergency medical services (GEMS) transport was obtained from a multilevel logistic regression model in patients actually undergoing HEMS transport or GEMS transport with transport time >15minutes to capture GEMS patients with the possibility of undergoing HEMS transport. This random coefficient model adjusted for age, sex, race, insurance, mechanism, prehospital vital signs, injury severity score (ISS), Trauma Mortality Prediction Model (TMPM) predicted mortality,[3] and trauma center level while including a random effect for centers to account for clustering and accounting for the possibility that the effect of HEMS transport on survival was different across different centers. An unstructured covariance structure was used for the random effects. A total of 838 centers (clusters) were included as random effects. The fixed effects portion of the model demonstrated a c-statistic of 0.93, indicating excellent discrimination, and had a Pearson Chi-square goodness-of-fit test p>0.999 indicating adequate calibration. Pearson residuals and empirical Bayes means of the random effects both demonstrated approximate normal distributions, upholding model assumptions.

To determine probability of survival for patients transported by HEMS under the AMPT score strategy, the same model described above was applied to only patients that had a concurrent AMPT score triage assignment and actual transport mode (i.e. AMPT assigned to HEMS and actual HEMS transport or AMPT assigned to GEMS and actual GEMS transport), again restricting GEMS patients to transport time >15minutes. This was done to produce the most conservative treatment-effect estimates for HEMS transport, as including patients that should have been transported by HEMS according to the AMPT score but were actually transported by GEMS may have high mortality and increase the apparent survival benefit of patients transported by HEMS when triaged to HEMS by the AMPT score.

Adjusted odds ratios (AOR) obtained from the random coefficient multilevel logistic regression models were applied to the NTDB for the treatment-effect of HEMS compared to GEMS. These AOR were then converted to a number need to treat using the following formula:[4]

$$NNT = ((CER*(AOR-1))+1)/(CER*(AOR-1)*(1-CER))$$

NNT, number needed to treat; CER, control event rate; AOR, adjusted odds ratio

The control event rate was set as the probability of survival in the GEMS group. The absolute change in probability of survival for HEMS transport was determined using the following formula:

$$\text{Absolute risk change} = 1/NNT$$

The absolute risk change was then added to the probability of survival in the GEMS group to obtain the probability of survival for the HEMS group.

For the base-case, an AOR of 1.08 (95%CI 1.01—1.17, p=0.03) for current practice and 1.11 (95%CI 1.02-1.22, p=0.02) for the AMPT score were obtained. This results in NNT of 278 and 218 respectively, with absolute risk changes of 0.0036 and 0.0046 respectively. Applied to the GEMS probability of survival of 0.9520, the probability of survival for HEMS under current practice is 0.9556, and under the AMPT score is 0.9566.

For the ISS structural sensitivity analyses, an AOR of 1.17 (95%CI 1.10—1.26, p<0.01) for current practice and 1.20 (95%CI 1.09—1.31, p<0.01) for the AMPT score were obtained in patients with an ISS>15. This results in NNT of 52 and 45 respectively, with absolute risk changes of 0.0193 and 0.0222 respectively. Applied to the GEMS probability of survival of 0.8467, the probability of survival for HEMS in patients with ISS>15 under current practice is 0.8660, and under the AMPT score is 0.8689.

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eMethods 4. Calculation of transport costs

Transport service charges were based on the Centers for Medicare and Medicaid Services (CMS) ambulance fee schedule.[5] For ground ambulance cost, the level of service and rurality were taken into account. The service levels considered were advanced life support (ALS) 1 – emergency, defined as any intervention applied under local protocols by an emergency medical technician-intermediate or paramedic in the context of an emergency response, and ALS 2, defined as administration of at least 3 intravenous boluses of medication or crystalloid, continuous intravenous infusion of medication or crystalloid, or any of the following procedures: manual defibrillation/cardioversion, endotracheal intubation, central venous line placement, cardiac pacing, chest decompression, surgical airway, or intraosseous line placement.

The National Emergency Medical Services Information Systems (NEMSIS) dataset is a national database containing information for EMS responses.[6] Data from 2012 constituting data from 37 states was used to evaluate the proportion of scene responses for trauma billing at the ALS 1-emergency or ALS 2 level of service. NEMSIS data was also used to determine the proportion of scene trauma transports coming from rural or super-rural (lowest 25th percentile of population density) zip codes based on CMS definitions. Only ALS services and rural/super-rural locations were considered, as patients from urban settings or only requiring basic life support would not likely require HEMS transport.

Charges for ground ambulance transport are calculated using a base charge plus mileage charge, with bonuses for higher level of service and more rural location. Additionally, a higher mileage charge is applied to the first seventeen rural transport miles. A weighted average base charge was calculated using the proportion of scene trauma calls with ALS 1-emergency or ALS 2 level of service and rural or super-rural location. The weighted base charge was added to the mileage charge based on the transport distance. Finally, the transport distance for GEMS was multiplied by a coefficient of 1.3, to reflect the equivalent driving distance compared to straight line flight distance a helicopter would take.[7]

The final formula for GEMS transport cost using logic operators to account for different mileage charges over the first seventeen miles was as follows:

*if((TransportDistance*1.3)≤17; 461.48+(11.02*(1.3*TransportDistance)); 461.48+((17*11.02)+(7.34*((1.3*TransportDistance)-17))))*

For helicopter transport, a flat rural base charge was added to the flat rural mileage charge based on transport distance.

The final formula for HEMS transport cost was as follows:

*5293.85+(34.16*TransportDistance)*

Table 2 shows CMS charges across service level and rurality with example calculations and charges for GEMS and HEMS.

Table 2. CMS ambulance fee schedule charges and weighted average charges based on transport distance for ground and helicopter ambulance costs (2015 US $)

Transport distance miles	10	25	55	85
GEMS equivalent miles	13	32.5	71.5	110.5
CMS base charges by service level and rurality				
GEMS rural base ALS1-E charge	$439.37	$439.37	$439.37	$439.37
GEMS rural base ALS2 charge	$635.93	$635.93	$635.93	$635.93
GEMS super-rural base ALS1-E charge	$538.67	$538.67	$538.67	$538.67
GEMS super-rural base ALS2 charge	$779.65	$779.65	$779.65	$779.65
GEMS per rural mile charge	$7.34	$7.34	$7.34	$7.34
GEMS per rural mile 1-17 charge	$11.02	$11.02	$11.02	$11.02
HEMS rural base charge	$5293.85	$5293.85	$5293.85	$5293.85
HEMS per rural mile charge	$34.16	$34.16	$34.16	$34.16
Proportion of 2012 NEMSIS scene trauma calls by service level and zip-code rurality				
Proportion of GEMS ALS1-E	0.94	0.94	0.94	0.94
Proportion of GEMS ALS2	0.06	0.06	0.06	0.06
Proportion of GEMS rural	0.89	0.89	0.89	0.89
Proportion of GEMS super-rural	0.11	0.11	0.11	0.11
Weighted average charged by service level across rurality				
Weighted average GEMS rural base charge by service level	$450.57	$450.57	$450.57	$450.57
Weighted average GEMS super-rural base charge by service level	$552.40	$552.40	$552.40	$552.40
Base and mileage charges for GEMS and HEMS transport				
Weighted average GEMS base charge by service level and rurality	$461.48	$461.48	$461.48	$461.48
GEMS equivalent mileage charge	$143.21	$301.10	$587.51	$873.92
HEMS rural base charge	$5293.85	$5293.85	$5293.85	$5293.85
HEMS mileage charge	$341.55	$853.88	$1878.53	$2903.18
Final charges by transport distance				
GEMS charge	$604.69	$762.58	$1048.99	$1335.40
HEMS charge	$5635.40	$6147.73	$7172.38	$8197.03
Not all decimals may add to 100 due to rounding				

eMethods 5. Annual health care expenditures

Annual lifetime healthcare costs after the first year post-injury were obtained from the CMS mean annual health expenditures across age groups and inflated by a factor of 1.45 for the base case, as well as patients with severe injury in the structural sensitivity analysis based on the proportion of patients with ISS>15 (Table 3).[8, 9] An inflation factor of 1.25 was used for patients with and ISS≤15 in the structural sensitivity analysis.[8, 9] These inflation factors represent the expected increased costs for health services utilization post-injury in severely injured and non-severely injured patients compared to a non-injured population over a longitudinal ten-year follow up period.[8] The annual cost was cumulatively added to a patient's total lifetime cost in each Markov cycle based on age in the cycle, and injury severity in the case of the ISS structural sensitivity analysis.

Table 3. Annual healthcare costs after the first year post-injury

Age (years)	Annual expenditure for base-case and severely injured patients with ISS>15 (2015 US $)	Annual expenditure for patients with ISS≤15 (2015 US $)
19 – 44	6,032	5,206
45 – 54	9,358	8,065
55 – 64	13,987	12,056
65 – 74	19,356	16,683
75 – 84	29,431	25,369
≥85	46,136	39,773

eMethods 6. Model inputs by Injury Severity Score for structural sensitivity analysis

The changes in probabilities, costs, and utilities based on an ISS≤15 and ISS>15 are shown in Table 4. These changes were modeled as weighted averages for patients with ISS>15 and those with ISS≤15.

Table 4. Model input assumption by injury severity score for structural sensitivity analysis

Variable	***ISS≤15***	***ISS>15***	***Source***
Length of stay (days)	3	6	NTDB
Cost of hospitalization	$14,252	$65,403	Delgado[9]
Cost of health care within 1 year after injury	$10,274	$39,109	Delgado[9]
Cost of health care >1 year after injury	CMS annual expenditures inflated by factor of 1.25	CMS annual expenditures inflated by factor of 1.45	Delgado[9]
Probability of in-hospital survival for GEMS patients	0.9864	0.8467	NTDB
Probability of in-hospital survival for HEMS patients assigned using AMPT strategy	0.9864	0.8689	NDTB
Probability of in-hospital survival for HEMS patients assigned using current practice strategy	0.9864	0.8660	NDTB
Probability of surviving 1 year after discharge alive	0.99	0.97	MacKenzie[10]
Utility during hospitalization	0.5	0.3	Assumed
Utility discharged alive	0.7	0.6	Delgado[9]
Utility 1 year after injury	0.8	0.7	Delgado[9]
Annual probability of mortality >1yr after injury	US annual life tables adjusted by hazard ratio of 1.38	US annual life tables adjusted by hazard ratio of 5.19	CDC,[11] Delgado[9]
Annual utility >1yr after injury	Health and Activity Limitation Index	Health and Activity Limitation Index decreased by 30%	Gold,[12] MacKenzie[13]

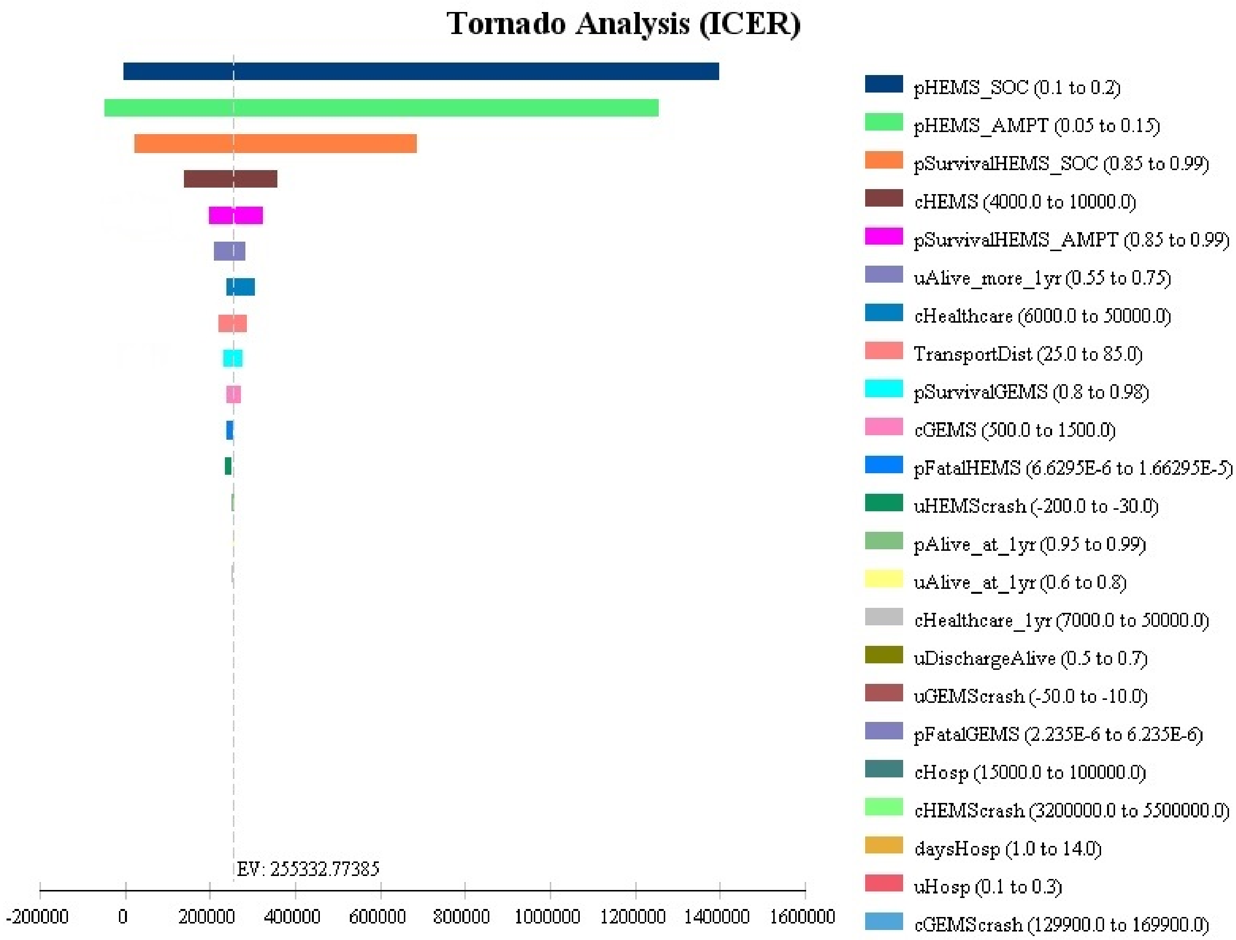
eMethods 7. Variable distribution parameters for probabilistic sensitivity analysis

Probabilistic sensitivity analysis was performed using 10,000 second-order Monte Carlo simulation trials. For each trial, all model input values below were randomly selected from the distribution in Table 5 with indicated distribution parameters to evaluate cost-effectiveness under those conditions, reflecting the uncertainty in each model input value.

Table 5. Variable distribution parameters for probabilistic sensitivity analysis			
Variable	***Base-case value***	***Distribution***	***Distribution parameters***
Age	47	Normal	Mean = 44.381; SD=25.524
Injury severity Score >15 (%)	20.46	Beta	α=(((0.2)^2)*(1-(0.2))/((0.15)^2)-(0.2)); β=((1-(0.2))*(((1-(0.2))*(0.2))/((0.15)^2)-1))
Length of stay (days)	3	Log Normal	μ=ln(3); σ=√(ln(5.790/3)*2)
Probability of HEMS transport under current practice strategy	0.165	Triangular	Min=0.100; Likeliest=0.165; Max=0.200
Probability of HEMS transport under AMPT strategy	0.095	Triangular	Min=0.020; Likeliest=0.095; Max=0.150
Transport distance (mi)	55	Triangular	Min=20; Likeliest=55; Max=85
Probability of fatal HEMS crash per mile traveled	1.6E-7	Triangular	Min=0.8E-7; Likeliest=1.6E-7; Max=3.1E-7
Probability of fatal GEMS crash per mile traveled	0.8E-7	Triangular	Min=0.4E-7; Likeliest=0.8E-7; Max=1.5E-7
HEMS service charge per patient	$7,172.65	Triangular	Min=$5,000; Likeliest=$7,173; Max=$10,000
GEMS service charge per patient	$1,048.85	Triangular	Min=$775; Likeliest=$1,050; Max=$1,500
Cost of hospitalization	$58,172	Normal	Mean=$58,172; SD=$80,407
Cost of health care within 1 year after injury	$36,593	Normal	Mean=$36,593; SD=$21,879
Cost of health care >1 year after injury	CMS annual expenditures	Triangular	Min=$5,000; Likeliest=$9,358; Max=$15,000
Vehicle cost of GEMS crash	$144,900	Triangular	Min=$129,900; Likeliest=$144,900; Max=$169,900
Vehicle cost of HEMS crash	$4.6 million	Triangular	Min=$3.2million; Likeliest=$4.6million; Max=$5.5million
QALYs lost in GEMS crash	30	Uniform	Low=10; High=50
QALYs lost in HEMS crash	120	Uniform	Low=90; High=150
Probability of in-hospital survival for GEMS patients	0.9520	Beta	α=(((.952)^2)*(1-(.952))/((.001)^2)-(.952)); β=((1-(.952))*(((1-(.952))*(.952))/((.001)^2)-1))
Probability of in-hospital survival for HEMS patients assigned using AMPT strategy	0.9566	Beta	α=(((0.957)^2)*(1-(0.957))/((.001)^2)-(0.957)); β=((1-(0.957))*(((1-(0.957))*(0.957))/((.001)^2)-1))
Probability of in-hospital survival for HEMS patients assigned using current practice strategy	0.9556	Beta	α=(((0.956)^2)*(1-(0.956))/((0.001)^2)-(0.956)); β=((1-(0.956))*(((1-(0.956))*(0.956))/((0.001)^2)-1))
Probability of survival within 1 year of discharge after	0.97	Beta	α=(((0.97)^2)*(1-(0.97))/((0.025)^2)-(0.97)); β=((1-(0.97))*(((1-(0.97))*(0.97))/((0.025)^2)-

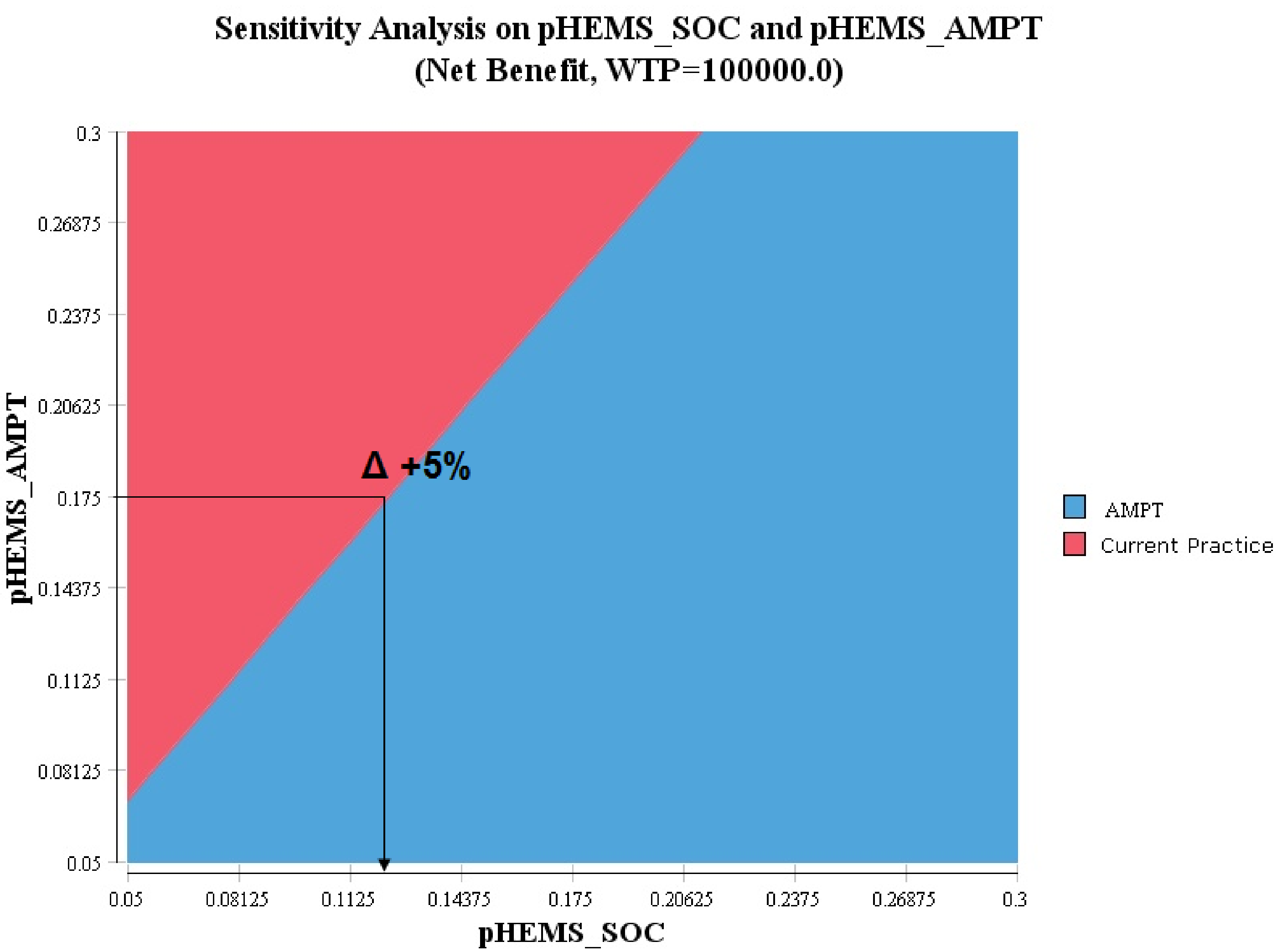
injury			1))
Utility during hospitalization	0.3	Triangular	Min=0.1; Likeliest=0.3; Max=0.5
Utility discharged alive	0.6	Normal	Mean=0.6; SD=0.1
Utility 1 year after injury	0.7	Normal	Mean=0.7; SD=0.05
Annual utility >1yr after injury	Health and Activity Limitation Index	Normal	Mean=0.65; SD=0.05

eFigure 1. Incremental cost-effectiveness ratio (ICER) tornado diagram from 1-way sensitivity analysis



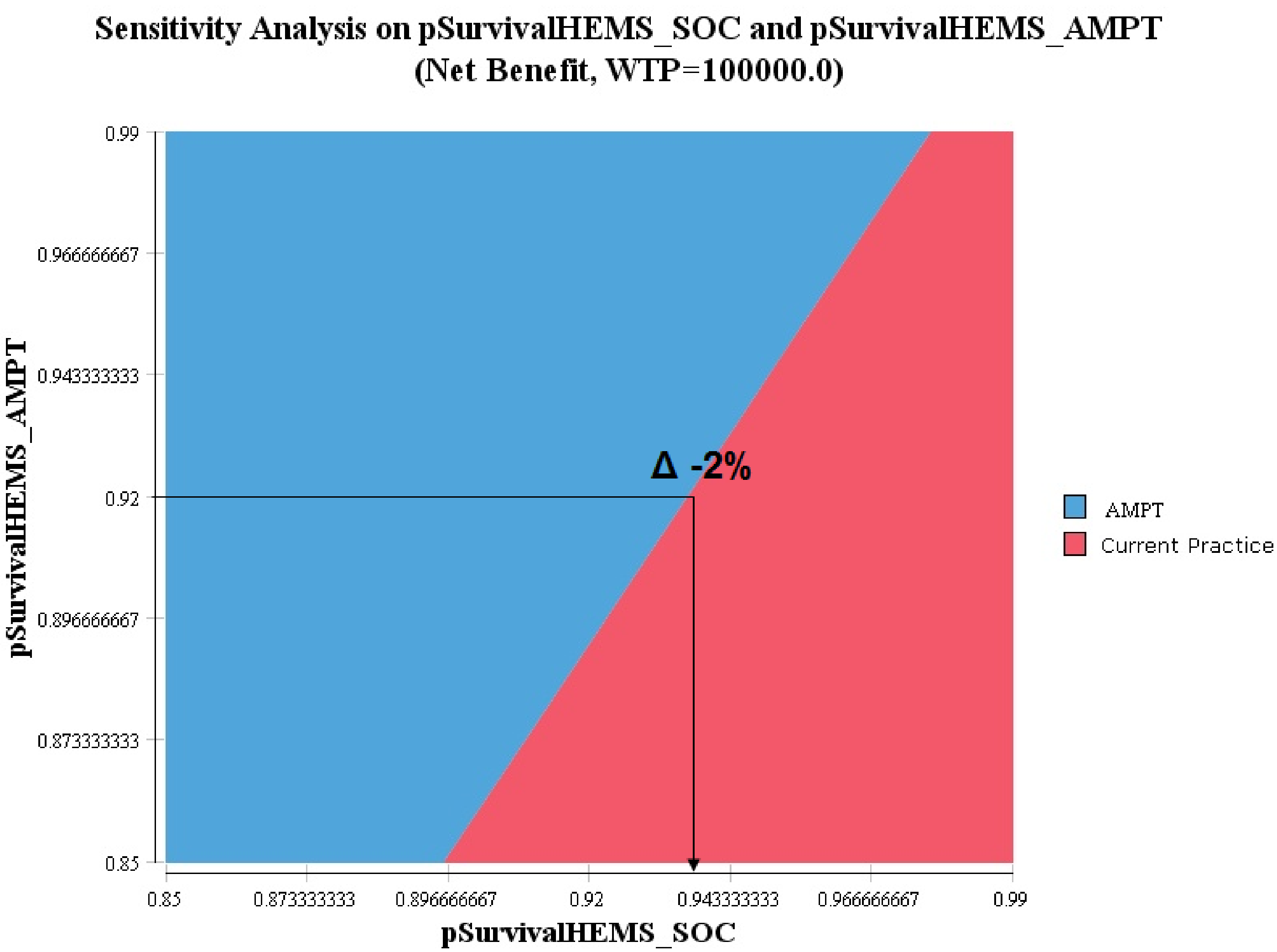
Size of bars represent relative influence of each model variable on the ICER across the range of values tested in sensitivity analysis. The probability of HEMS transport for current practice (pHEMS_SOC), probability of HEMS transport for the AMPT score (pHEMS_AMPT), probability of survival for HEMS transport for current practice (pSurvivalHEMS_SOC), cost of HEMS transport (cHEMS), and probability of survival for HEMS transport for the AMPT score (pSurvivalHEMS_AMPT) were the five most influential model inputs.

eFigure 2. Two-way sensitivity analysis of probability of helicopter emergency medical services (HEMS) transport under the Air Medical Prehospital Triage (AMPT) score triage strategy (pHEMS_AMPT) and probability of HEMS transport under the current practice triage strategy (pHEMS_SOC)



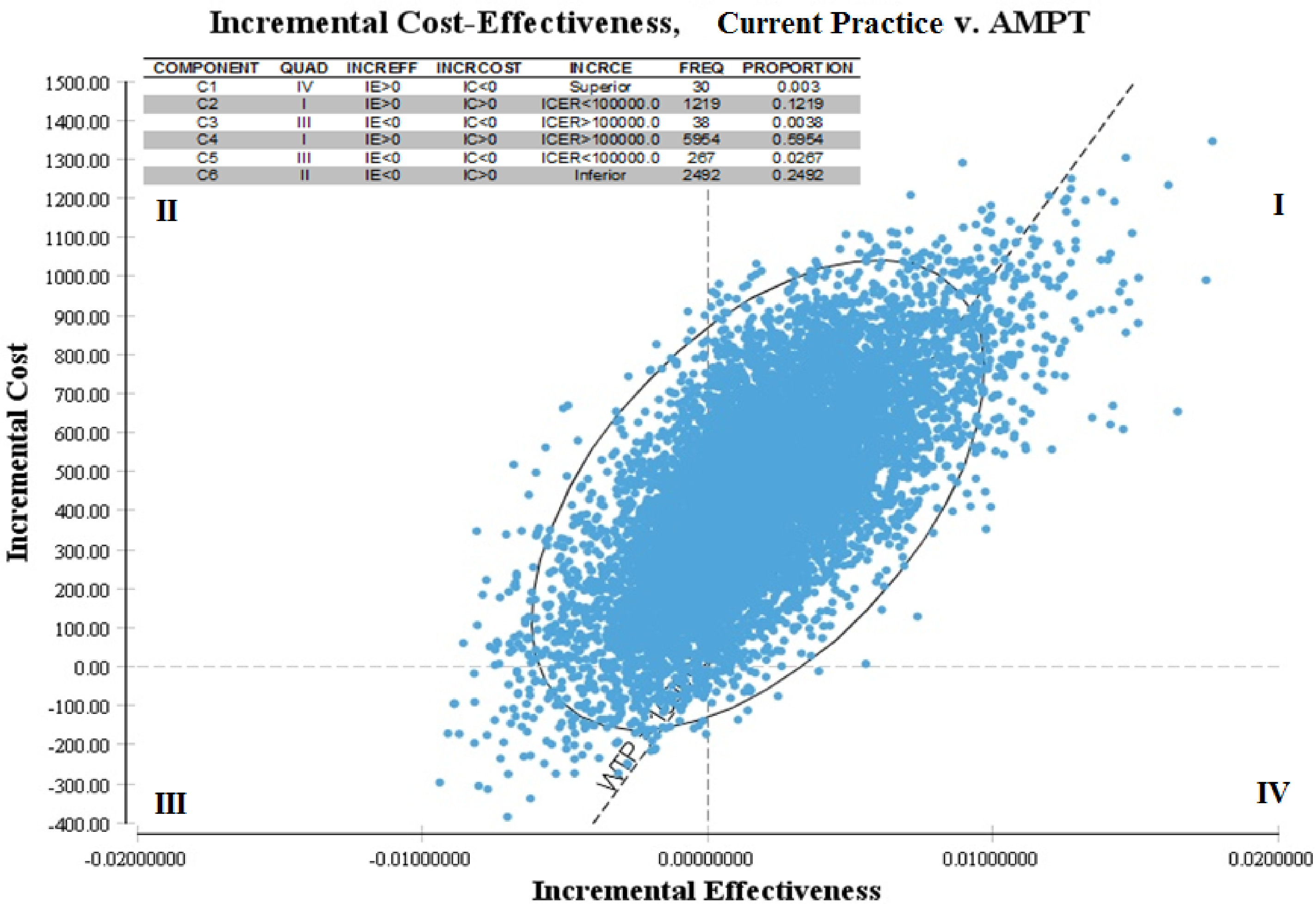
Blue area represent pairs of these values were the AMPT strategy is more cost-effective and red area represent pairs of these values were the current practice strategy is more cost-effective. Black arrow demonstrates that for current practice to be the cost-effective strategy, the AMPT score would have to have to have a probability of HEMS transport more than 5% greater than current practice (i.e. the AMPT strategy would have to triage 17.5% of patients to HEMS transport while current practice only triaged 12.5% of patients to HEMS transport).

eFigure 3. Two-way sensitivity analysis of probability of survival for helicopter emergency medical services (HEMS) transport under the Air Medical Prehospital Triage (AMPT) score triage strategy (psurvivalHEMS_AMPT) and probability of survival for HEMS transport under the current practice triage strategy (psurvivalHEMS_SOC)



Blue area represent pairs of these values were the AMPT strategy is more cost-effective and red area represent pairs of these values were the current practice strategy is more cost-effective. Black arrow demonstrates that the AMPT score remains the most cost-effective strategy until mortality of HEMS patients using the AMPT score was more than 2% greater than the mortality of HEMS patient under current practice (i.e. the AMPT strategy HEMS patient mortality of 8% with a current practice HEMS patient mortality of 6%).

eFigure 4. Probabilistic sensitivity analysis with 10 000 Monte Carlo iterations by incremental cost and effectiveness comparing the current practice strategy with the AMPT score strategy for HEMS triage



COMPONENT	QUAD	INCREFF	INCRCOST	INCRCE	FREQ	PROPORTION
C1	IV	IE>0	IC<0	Superior	30	0.003
C2	I	IE>0	IC>0	ICER<100000.0	1219	0.1219
C3	III	IE<0	IC<0	ICER>100000.0	38	0.0038
C4	I	IE>0	IC>0	ICER>100000.0	5954	0.5954
C5	III	IE<0	IC<0	ICER<100000.0	267	0.0267
C6	II	IE<0	IC>0	Inferior	2492	0.2492

Diagonal dotted line represents $100,000/QALY willingness-to-pay threshold for cost-effectiveness. Results demonstrate current practice compared to the AMPT score is not cost-effective in 59.92% of iterations (C3+C4), inferior in 24.92% of iterations (C6), cost-effective in 14.86% of iterations (C2+C5), and superior in 0.3% of iterations (C1). Overall the AMPT score is the favored strategy in 84.84% of iterations based on probabilistic sensitivity analysis.

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