THE EFFECT OF AIR MEDICAL TRANSPORT ON SURVIVAL AFTER TRAUMA IN JOHANNESBURG, SOUTH AFRICA

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Objectives. To assess the difference in survival of trauma patients transported to a trauma unit via either road or air in Johannesburg, South Africa.

Design. Prospective database analysis.

Setting. Multicentre study utilising two trauma units.

Subjects. The study evaluated 428 subjects admitted to the two sites.

Outcome measures. Actual survival rates in each group (road and air) were compared with the predicted survival rates.

Results. In the road group, 38.96 people were predicted to die and 51 actually died, therefore 23.61% (or 12.04 people) died 'unnecessarily', i.e. they died after having been predicted to live. In the helicopter group, 38.15 people were predicted to die and 39 actually died, therefore 0.85 (39 - 38.15) people were not expected to die. The 0.85 people represent 2.18% (0.85/39) of the total number of dead in the helicopter group who died 'unnecessarily'. Therefore one could argue that introduction of helicopter transport reduces the number of dead by 21.43% (23.61 - 2.18).

Conclusions. Patients with a certain injury severity are more likely to survive if transported by air to a trauma unit.

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The Johannesburg-based 'Flight for Life' helicopter emergency medical service (HEMS) was established in September 1977 and is still one of the few services outside of the USA that operates on a 24-hour basis. In addition to this service, two other emergency medical helicopters operated in the Gauteng region in the latter part of 1999.

This empirical research assessed death rate data to ascertain if the air medical transport (AMT) of patients results in lower death rates than occur with road transportation of patients.

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METHODOLOGY

This study compares the outcome (measured in terms of being discharged from hospital alive) for patients transported to a trauma centre by means of a helicopter ambulance with the outcome for patients transported by road. 'Transport by road' refers to road-based emergency medical services and to patients brought in by non-medical personnel, e.g. family, friends or bystanders.

This study utilises TRISS (an acronym derived from the terms Trauma Score and Injury Severity Score) methodology[1,2] that facilitates the prediction of the survival. The survival probability for each patient is based on an assessment of confirmed injuries and observed physiological and age characteristics.

Each patient entering one of two trauma units was allocated a score by evaluating the injuries sustained, his/her age, physiological status and the mechanism of injury. Once the score was allocated it was compared with a database of 80 544 patients who formed the cohort group known as the Major Trauma Outcome Study (MTOS).[3] In this way the individual's probability of survival (Ps) was assessed.

If a patient survived when it was predicted that she/he would die, one could say that the treatment received by the patient was of a particularly high standard. On the other hand a patient who died but was expected to live indicates a problem in the chain of trauma care.

As both HEMS patients and non-helicopter patients were evaluated in this study, a survival probability comparison was possible. In order to make the findings more representative of the South African medical environment, patients were evaluated at the trauma units of both a private and a government hospital.

The trauma units of Milpark Hospital (private sector) and Johannesburg Hospital (public sector) work on a similar system. Patients with minor injuries are seen in 'casualty' and more seriously injured patients are treated in the 'resuscitation

Specialised Trauma Air Response's EC 120, based in Durban.

room'. In the latter case patients are treated by doctors, nurses, paramedics, radiologists and the on-duty trauma surgeon.

With the exceptions noted below the patient records of all patients admitted directly from the scene of injury were assessed in order to acquire the relevant information. Patients included in the study were seen in the resuscitation room at Milpark Hospital during the period 1 July 1999 - 1 November 1999 and at Johannesburg Hospital between 1 September 1999 and 30 January 2000.

Although the one period includes the festive season this did not impact on the study's results as all patients were evaluated using the same 'yardstick'. The condition and outcome of the patients were measured according to the same process, which was not affected by the time of year.

It should also be noted that statistical analysis showed no significant differences between hospitals with regard to the mean probability of patient survival or the actual proportion of surviving patients. Similarly, non-significant differences between hospitals were observed for several other variables (e.g. proportion of correct predictions). Therefore 'hospital' was not considered an important variable in the study and was omitted from later analysis.

Excluded from the study were patients who: (*i*) were admitted as a result of a medical emergency that was not trauma related, i.e. patients admitted as a result of natural medical emergencies; (*ii*) had been treated at another hospital before admission to the resuscitation room; (*iii*) were transferred to another hospital before a full diagnosis of injuries could be made; (*iv*) were brought into the hospital and showed no signs of life, e.g. decapitation or rigor mortis; (*v*) had records that were incomplete resulting in inadequate data being available; and (*vi*) arrived at the trauma unit without a blood pressure (BP) reading or any sign of spontaneous respiration.

This left 428 cases for analysis.

The date of death was listed if the patients died in hospital; all other patients were considered to have been discharged alive.

The patient records were reviewed for patient age, mechanism of injury (blunt or penetrating), emergency room BP, Glasgow Coma Scale (GCS), respiratory rate (RR), confirmed injuries, date of admission and date of death or discharge. The first set of in-hospital data were used. In cases where the first BP reading was taken manually and the second was taken using more accurate, automated medical instrumentation, the second BP measurement was used.

The data were all captured on the National Tracs computer system developed by the American College of Surgeons. Version 2.5D of the software (October 1997) was used. The software collated the input data and gave the patients' individual Ps scores.

Data collected from Milpark Hospital were compiled from each patient's file by one of the authors and then entered onto the National Tracs computer system. Data from Johannesburg Hospital were already recorded on the National Tracs system by staff of the trauma unit. The methodology used in each hospital was exactly the same.

An inevitable weakness in the methodology is the nature of the experimental design. It is ethically and logistically implausible to randomise potentially critically ill and injured patients in order to conform to a controlled, prospective experimental design. Therefore such studies have generally used a 'with or without' quasi-experimental design, which resulted in stronger conclusions than would be achieved with a simple case series, even though there was no true control group. Criticisms of this technique have been noted in a number of similar studies.[4,5]

An additional area of concern relates to the data contained in the MTOS database that was used to gain comparable patient outcomes. There are three limitations of this comparison, namely: (*i*) the database was compiled well over a decade ago and since then standards of trauma care have improved substantially (however, studies evaluating trauma care systems in the developed world have utilised the MTOS database as recently as 1999);[5] (*ii*) 139 trauma centres were used in the MTOS study representing different levels of care, while only two centres were used in this report; and (*iii*) the data are from the USA and not South Africa.

However, there is no better trauma outcome group available.[5] In addition to this the primary aim of the current study was to review the outcome of patients transported by two different means against a particular reference point. The exact position of that reference point is not as important as the position of the two groups in relation to it. Using this rationale the authors believe that the MTOS database is an extremely useful reference point even in the developing world.

An additional problem is that certain patients included in the study will have died of non-trauma-related complications. For example, an elderly patient admitted to hospital with a fractured hip and low blood pressure may die of a heart attack while in surgery. The TRISS methodology will falsely identify this situation as a failure in trauma system.[6] However, both groups studied in this paper were subject to this flow.

RESULTS AND DISCUSSION

Descriptive statistics

Tables I - III present the data used to assess the mortality rates for each group.

If one compares the number of dead in each group as a percentage of the total number of patients in that group, it will be seen that a greater percentage died in the helicopter group (32%) than in the road group (16.7%). Looking at these data in

Table I. Helicopter group mortality rate

	Died	Lived	Total
Predicted to die (Ps < 0.5)	26	13	39
Predicted to live (Ps > 0.5)	13	70	83
Total	39	83	122

Table II. Road group mortality rate

	Died	Lived	Total
Predicted to die (Ps < 0.5)	31	5	36
Predicted to live (Ps > 0.5)	20	250	270
Total	51	255	306

Table III. Mortality rate for the combined groups

	Died	Lived	Total
Predicted to die (Ps < 0.5)	57	18	75
Predicted to live (Ps > 0.5)	33	320	353
Total	90	338	428

isolation, without taking patient condition and injuries into consideration, leads to the perception that helicopters are not advantageous. This would be a false impression as the helicopter group includes a much higher percentage of severely injured patients, and therefore more patients are expected to die.

Z-statistic

In calculating the Z-statistic, all the Ps scores are added to get the total number of people predicted to die within a group. This figure is then compared with the number of people who died in the MTOS group, which forms the baseline. Once one knows how many people were predicted to die then one can assess if a particular intervention leads to a greater or lesser number of people dying than expected.

The increase in mortality in the helicopter group was not statistically significant (from standard normal distribution tables). In the road group there were 12.04 (51 - 38.96) unpredicted deaths, which was significant. The difference between the predicted and realised mortality between the two groups was also statistically significant.

The final Z-statistic indicates that there is a smaller chance of survival in the road group than in the air group. As the trauma units used for both groups were the same and the methodology makes allowances for the difference in injury severity, this indicates that there is something in the mode of transportation to hospital that leads to a decreased survival rate in the road group. Exactly what causes this difference is not immediately obvious and will be discussed later.

M-statistic

The M-statistic is used to evaluate if patients in the sample group have a similar distribution of injuries to patients in the MTOS group. In the two study groups, helicopter and road-based, the M-statistic was 0.618 and 0.867 respectively. Both of these figures are lower than the MTOS cohort group, and it is felt that this is quite understandable. The MTOS group included all admissions to hospital due to trauma and therefore did not exclude the minor injuries that have been excluded in the present study.[7] A further factor is that helicopters are only called when patients have suffered severe, life-threatening injuries or when road transport is not appropriate.

However, it is felt that the methodology employed in this research 'corrects' for the different injury profiles, and that the findings are not invalidated by the above M-statistic.

Further thoughts on survival probabilities

In the analyses above the patients assessed were divided into two groups — those predicted to live and those predicted to die. In Table IV a finer analysis is undertaken using four arbitrarily chosen categories of survival probability.

Of the 51 people who had a lower than 35% (Ps < 0.35) chance of survival, 17.64% (9/51) lived. In the road group, 8% (2/25) lived, whereas in the helicopter group this survival rate was 26.92% (7/26). This difference is significant at a 10% level based on Fisher's exact probability test ($P = 0.078$). In the group

Table IV. Lived/died statistics in four Ps ranges

	0 - 0.35			0.35 -0.5			0.5 - 0.65			0.65 - 1		
	Total	H	R	Total	H	R	Total	H	R	Total	H	R
Died	42	19	23	15	7	8	7	4	3	26	9	17
Lived	9	7	2	9	6	3	12	7	5	308	63	245
Total	51	26	25	24	13	11	19	11	8	334	72	262

H = helicopter; R = road.

with Ps scores between 0.35 and 0.5, 37.5% (9/24) lived when they were predicted to die. This equates to a survival rate of 46.15% (6/13) in the helicopter group and 27.3% (3/11) in the non-helicopter group, a statistically non-significant difference.

In the group with Ps scores greater than 0.5, everybody was expected to live and 90.65% (320/353) did survive. In the road group, 8 people fell into the Ps range 0.5 - 0.65. Of those, 62.5% (5/8) survived compared with 63.63% (7/11) in the helicopter group (again non-significant as a difference). In the group with Ps scores greater than 0.65, 92.2% (308/334) survived. In the road group, 93.5% (245/262) of the patients lived as predicted, compared with 87.5% (63/72) in the helicopter group (Fisher's test significant at 10% level ($P = 0.080$).

The interpretation of the above appears to indicate that if a patient has a Ps score below 0.65, then she/he has a greater chance of survival if transported by helicopter. This situation is most noticeable in the range 0.35 - 0.5, where the difference between helicopter and road is most exaggerated. If a patient has a Ps score over 0.65, the data suggest that she/he has a better chance of survival if transported by road.

However, predicting the Ps accurately before calling the helicopter is exceptionally difficult as road crews cannot categorically define exactly what the patient's confirmed injuries are, and therefore cannot calculate an accurate Ps score. This means that helicopters will sometimes be called when statistically they have been proved to be of little help, and on other occasions they will not be called when the research shows that they would have been advantageous to the patient.

Differences in survival rates

The results for the two groups are compared in Table V.

The road transport group included patients who came into hospital without receiving any pre-hospital emergency care as well as those who received care at the basic, intermediate and advanced life support levels. On the other hand, all the patients in the helicopter group received sophisticated advanced life support. Therefore it is thought that the superior level of medical intervention played a large role in the improved survival rate of the helicopter group. This is supported by a comparison of the average Ps scores for all the people who died. The average for the road group was 0.483 compared with 0.426 for the helicopter group although the difference is not statistically significant. Looking at this score in conjunction with the Z-statistic, one sees a higher survival rate in the helicopter group even though the patients were more severely injured.

Table V. Statistical summary of all patients reviewed

	Helicopter group	Road group
Total number of patients	122	306
Mean Ps of dead patients	0.426	0.483
Expected to die	38.15	38.96
Actual number of dead	39	51
Z-statistic	0.223 ($P > 0.05$)	2.939 ($P < 0.05$)
Difference in Z-statistic*	1.921 ($P < 0.05$)	

$$* Z_{Difference} = \frac{Z_{Helicopter} - Z_{Road}}{\sqrt{2}}$$

If one compares (using the sum of the Ps scores) the overall outcome for both groups, it can be seen that of the people who died in the road group, 12.04 (51 - 38.96) were not predicted to die. The 12.04 people represent 23.61% (12.04/51) of the total number of dead in the road group who died 'unnecessarily'. In the helicopter group, 38.15 people were predicted to die and 39 actually died, therefore of those who died 0.85 (39 - 38.15) people were not predicted to die. The 0.85 people represent 2.18% (0.85/39) of the total number of dead in the helicopter group who died 'unnecessarily'. Therefore one could argue that the introduction of the helicopter reduces the number of dead by 21.43% (23.61 - 2.18).

Reliability of predictions

Of the total number of patients surveyed, 11.9% (51/428) defied the prediction of the TRISS score. It is felt that this figure is not particularly high as medicine is not an exact science. In addition, one must also recognise that the data on which the predictions are based (the MTOS cohort group) are not South African and therefore do not reflect the South African health care system.

The active ingredient

One must be careful not to make unsupported claims as a result of this study. The study set out to evaluate the effect of HEMS on mortality and did not attempt to evaluate what aspect of the HEMS leads to a difference in the mortality rates compared with the non-helicopter group.

It might be concluded that it is speed of response to the scene and subsequently speed of transport to hospital which lead to increased survival. However, in many cases the time taken to obtain definitive medical care is not reduced. The helicopter is only dispatched after the road-based emergency services have arrived on the scene and assessed the need for an air ambulance. Thus transport to hospital is often delayed by waiting for the helicopter to arrive.

Therefore, one has to accept that helicopter transport improves patient survival rate, but the exact reason for this decreased mortality has not been pinpointed in this research.

Certainly all attempts to identify alternative explanations for the different survival rates have been unsuccessful and have shown mode of transport to hospital to be the most significant variable. For instance, logistics regression analysis with correct prediction from the TRISS methodology (1 = correct, 0 = incorrect prediction) as the dependent variable and a variety of other variables as explanatory variables gave the results shown in Table VI.

Table VI shows that in addition to helicopter transport as a

Table VI. Logistics regression report

Response variable: Correct prediction

Parameter estimation section

Variable	Regression coefficient	Standard error	Probability level
Intercept	3.323	0.510	0.000
Days (in hospital)	0.005	0.010	0.602
Blunt (1 = blunt)	0.054	0.400	0.893
Age	–0.019	0.011	0.076
Hospital (1 = JH)	–0.463	0.333	0.164
Helicopter (1 = helicopter)	–1.300	0.400	0.001

JH = Johannesburg Hospital.

highly significant variable, only the patient's age is possibly significant ($P = 0.076$). Not surprisingly, the older the patient the less likely the TRISS methodology is to predict the probability of survival or death correctly.

CONCLUSION

Helicopters clearly deserve a place in the emergency care of trauma victims. However, this is only one link in the chain that will ultimately lead to either death or survival. For it to be successful, it must link reliable, efficient emergency medical services (road-based) and effective trauma centres that are staffed appropriately with a committed team of health care professionals. If used appropriately there appears to be little doubt that these expensive machines can play an important role in preventing certain unnecessary deaths while reducing costs for both individuals and health care facilities.[8,9]

References

1. Boyd CR, Tolson MA, Copes SW. Evaluating trauma care: The TRISS method. *J Trauma* 1987; **27:** 370-378.
2. Baker SP, O'Neil B, Haddon W, *et al.* The injury severity score: A method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974; **14:** 187-196.
3. Champion HR, Copes WS, Sacco WJ, *et al.* A new characterization of injury severity. *J Trauma* 1990; **30:** 539-546.
4. Eisenberg SM, Copass KM, Hallstrom PA, *et al.* Treatment of out-of-hospital cardiac arrests with rapid defibrillation by emergency medical technicians. *N Engl J Med* 1980; **302:** 1379-1383.
5. Jacobs LM, Gabram SG, Sztajnkrycer MD, *et al.* Helicopter air medical transport: ten-year outcomes for trauma patients in a New England program. *Conn Med* 1999; **63:** 677-682.
6. Pories SE, Gamelli RL, Pilcher DB, *et al.* Practical evaluation of trauma deaths. *J Trauma* 1989; **29:** 1607-1610.
7. Champion HR, Copes WS, Sacco WJ, *et al.* The Major Trauma Outcome Study: Establishing national norms for trauma care. *J Trauma* 1990; **30:** 1356-1365.
8. Champion HR. Helicopters in emergency trauma care (Editorial). *JAMA* 1983; **249:** 3074-3075.
9. Moylan JA. Impact of helicopters on trauma care and clinical results. *Ann Surg* 1988; **208:** 673-677.

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SPECIAL ARTICLE

EXPLORING THE COSTS OF A LIMITED PUBLIC SECTOR ANTIRETROVIRAL TREATMENT PROGRAMME IN SOUTH AFRICA

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Background. The role of antiretroviral treatment for adults in the pubic sector in South Africa is debated with little consideration of programme choices that could impact on the cost-effectiveness of the intervention. This study seeks to explore the impact of these programme choices at an individual level, as well as explore the total cost of a rationed national public sector antiretroviral treatment programme.

Methods. Eight scenarios were modelled of limited national treatment programmes over the next 5 years, reflecting different programme design choices. The individual cost-effectiveness of these scenarios were compared. The total costs of the most cost-effective scenario were calculated, and the potential for savings in other areas of health care utilisation was explored.

Results. The direct programme costs per life-year saved varied between scenarios from R5 923 to R11 829. All the costs of the most cost-effective scenario could potentially be offset depending on assumptions of health care access and utilisation. The total programme costs for the most cost-effective scenario in 2007 with 107 000 people on treatment are around R409 million.

Conclusion. Specific policy choices could almost double the number of people who could benefit from an investment in a limited national antiretroviral treatment programme. Such a programme is affordable within current resource constraints. The consideration of antiretroviral treatment calls for a unique public health approach to the rationing of health services in the public sector.

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