

# Entwicklung eines Modells für die Luftrettung

Development of a model for air rescue services

Blair Munford (AUS)

Eminent chairmen, fellow air medical professionals. Somehow at conferences I always find myself scheduled to speak immediately after lunch – perhaps this is because as an anaesthetist, I am expected to put you all to sleep! I promise to try and avoid this. Firstly I wish to apologise on behalf of my co-author Dr. Sean Beehan, who was originally presenting this paper. Unfortunately, urgent administrative matters have forced him to remain in Australia.

The combination of air transport with medicine, which has been predominantly but not exclusively patient transport, dates back to at least 1915 (1). This paper reviews models developed for air medical services and attempts to further develop and integrate some of these, to explain and predict usage of air medical services within the setting of the total health system.

The scope of air medical practice can encompass the following:

- Firstly, provision of medical services to the patient at location. This may be elective or acute and range from elective health clinics in remote areas, through elective or emergent flying specialist services to small hospitals, to flying in medical teams to disaster scenes.
- Secondly, provision of medical equipment, supplies or resources. This is usually acute – for example can include supply of blood, antivenene, or cardiac pacing or ballon pump devices. This should be considered separately from provision of transport, as in many instances it is the delivery of specialised equipment per se that is the crucial step.
- Thirdly, provision of patient transport. Again, this can be elective or acute, from routine transfers to (or from) facilities, through to critical care transport of the severely ill or injured, and includes the use of regular passenger transport services.

- Fourthly, extrication of patients from difficult locations, such as boats, cliffs, canyons or water. This usually means by rotorcraft.

It may be valid to supply medical resources or services, or to transport patients by air for one of three reasons:

- Firstly, where the distance involved is such, that air is the normally accepted mode of transport.
- Secondly, if distance is shorter than mandates air transport, but air is faster, or smoother (where this is a valid clinical consideration) than ground transport. This includes allowing fewer skilled or specialised teams to cover a greater area.
- Thirdly, where access or extrication is only practical by air, such as the use of rescue hoists.

The potential need for air medical services can partially be predicted by the population density or densities in the area of service: as this usually correlates well both with services available locally, and the likely volume of work. A simple analysis, developed by Dr. Beehan and myself for an Australian review of air medical services (2), produced three demographic models for air medical services:

- Firstly, is the *remote region model*, characterized by areas of extreme isolation or very sparse population with little in the way of an intrinsic health structure, – for example Northern Manitoba in Canada, the (former) “Homeland” areas in South Africa, and the Australian “outback”. Here almost all health care, both routine and emergent, must be supplied by air – either by delivering the care to the patient, or vice versa. Interfacility transport is likely to be rare – as there are few referring facilities. Routine general medical

clinic flights or similar, and scene response for even relatively minor illness and injury are characteristic categories of air medical practice in remote regions.

- Secondly, is the *rural region model*, less extreme than the remote model, but still sparsely populated regions with occasional towns and cities; for example: much of Scotland, the pastoral region of Australia, and states like Montana, Wyoming or Arizona in the USA. Such areas are likely to have access to basic routine and emergency medical services; with established referral patterns to few tertiary centres or even only one. Such referral patterns may be appropriate to be serviced by air; in addition some patients such as trauma victims may be airlifted from scene straight to the tertiary centre. The likelihood of an individual patient event requiring air delivered treatment or air medical evacuation is much lower than in the remote scenario, but this is counterbalanced by the larger population.
- Thirdly, is the *para-urban region model* exemplified by Western Europe. This area is usually characterized by comprehensive basic medical facilities, and within the region as a whole, superficially similar abundance of tertiary facilities. However, paradoxically, access to tertiary facilities may be extremely poor due to urban sprawl and road systems unable to provide rapid access by ground transport. This in itself has been quoted as a justification for a helicopter emergency medical service by Fischer et al. (3). There is also, by definition, a large population, some of whom will engage in hazardous recreational pursuits, close to their homes. Hence, many urban centres are ringed by a zone of potential recreational trauma, that may be isolated from conventional EMS response, for example rock climbing, white water rafting, off road motor-cycling and skiing to name a few.

In summary, air medical services may be required across the whole spectrum of population densities and terrain types, with the decreased proportion of medical services requiring aerial delivery offset by the increased population requiring these services. The more remote regions are the domain of the general purpose air medical service, covering few people but much terrain, while in the

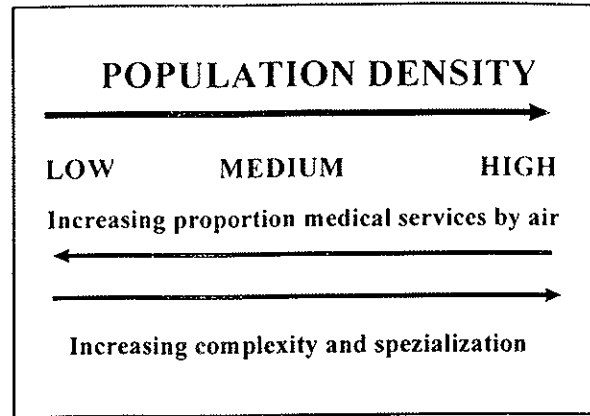


Figure 1:  
Population Density Model

more populous regions the demand is for specialized or critical care services covering the converse.

When we looked at justification of air medical transport earlier, a major point was provision of quicker transport. Smith, et al. at Penn State University have developed a model to predict when rotary wing scene response should be used, based purely on time to hospital (4).

The initial model assumes ground ambulance services are already at scene when the decision is made to transport the patient, and that the helicopter can land at scene (so no secondary transport).

The time to hospital by air,  $T_{air}$  is equal to liftoff time, plus outward flight time, plus time spent at scene plus return flight time; but  $T_{out} = T_{in}$ , where the destination is the helicopter's base hospital, and both are equal to distance  $D$  divided by mean helicopter speed  $V_{air}$ . Hence:

$$\text{Time by air} = 2D \text{ divided by mean airspeed} + \text{liftoff \& scene times}$$

while by road ambulance:

$$\text{Time by ground, } T_{ground} = D \text{ divided by mean ground speed } V_{ground}.$$

Note that  $V_{ground}$  is less than the mean road speed due to non straight line transport – the usual ratio or triangulation factor being around 1.4. so a mean road speed of 85 km/h, would give a  $V_{ground}$  of 60 km/h, or 1 km/min.

This is shown graphically here with one line being road ambulance proceeding steadily to hospital and the other line being the four phases of helicopter transport. This shows a single scenario at a distance where air and ground times are equal.

If we then allow a liftoff time of 7 minutes, scene time of 10 minutes, and mean helicopter speed of 210 km/h (= 3.5 km/min) then we can calculate that:

$$T_{air} = T_{ground}$$

when  $D = 39.5 \text{ km}$

becomes the (intersecting) point shown on the distance line. Hence for distances above 40 km, patients can usually be more rapidly delivered to a trauma hospital by rotorcraft. Obviously this will vary for different services and locations. Slower helicopters, longer launch times, faster ambulances (or better roads) all increase "D" and vice versa.

This model can be extrapolated into a number of other scenarios. For entrapped patients the enforced prolongation of scene time enhances the time advantage of rotorcraft. If entrapment time is longer than liftoff and outward flight time, then, as shown here where the patient remains at "D" for a prolonged period, the extra speed of air confers some advantage even over short distances.

The model assumes no difference in care between air and ground EMS teams, i.e. air response is viewed only as a means of getting the patient to care, and not additional care to the patient. To further develop this concept, we need first to look at another model, developed to study provision of advanced care within a certain time frame.

Bruhn et al. investigated the costs of delivery of advanced life support/critical care services within the state of Massachusetts by air versus by ground based units (5). The model is based on a 30 minute maximum response time with the same level of care.

To provide this service within the area covered by one helicopter required 6.7 (i.e. 7) ground units at a cost of 2.26 times that of the helo system. The study noted that the principle disadvantage of the helicopter system was the inability to respond to simultaneous requests – in practice this is achieved by backup from a neighbouring program, and factored in ground backup for this and

flights unable to be completed due to weather. This reduced the cost advantage of helicopter transport from 1 to 1.59.

If we then proceed to factor in medical care into the time model of Smith et al., then there will be a cohort of patients for whom the provision of more advanced levels of care than offered by ground ambulance teams at scene and in transit accrues a benefit – for example, those requiring advanced airway-management with muscle relaxants, tube thoracostomy, or blood transfusion.

In these situations, the time variable then becomes time till therapeutic intervention and the equation becomes times of: patient to (hospital) team, versus to (air medical) team to patient. For the same parameters shown earlier, air response offers time advantage over much shorter distances. The equation then becomes:

$$\begin{aligned} &\text{Ground transport time } T_{ground}, \text{ equal to} \\ &\text{distance } D \text{ over mean ground speed} \\ &\text{versus} \\ &\text{Advanced care team time to patient} \\ &T_{response}, \text{ equal to liftoff time plus} \\ &\text{distance over mean airspeed.} \end{aligned}$$

On the same variables as earlier, we can then calculate that:

Air response time is shorter than ground transport time when  $D$  is over 10 km.

This seems like a very short distance, and it is. It would seem reasonable to add in a factor to ensure helicopter utilisation only when it is of *significant* advantage. If we make this interval ten minutes, then:

Air response time is *significantly* shorter than ground transport when  $D > 23.8 \text{ km}$  or say 25 km.

So we can make the following recommendations for a situation with the variables given earlier:

- If the patient is free of entrapment and stable, but requires rapid transport, use helicopter transport if over 40 km, and ground ambulance if under this.
- If patient is unstable, deteriorating, or trapped use helicopter transport if over 25 km.

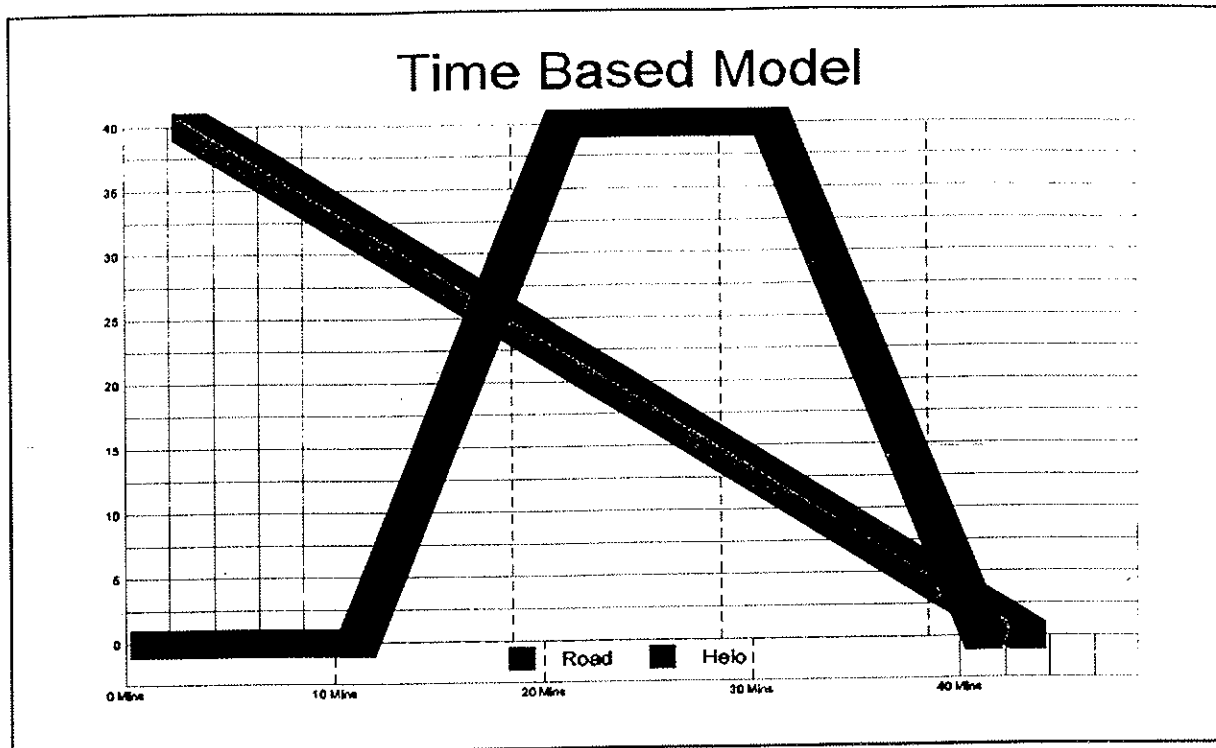


Figure 2:  
Road versus helo-transport model

- For entrapped patients under 25 km, consider critical care team response by road.

Note, that where the air and ground teams have similar skill levels, then only the time based model can apply. This is consistent with Schiller et al.'s study showing urban helicopter transport to have no outcome advantage over ground transport with the same staffing and clinical protocols (6).

Recently, a very sophisticated computer based model has been developed for air ambulance system analysis, design and optimization in Ontario, Canada by Stundzia and Lumden (7). Apparently applicable to a wide scope of air medical operations, the published study examined only helicopter interhospital transports.

Different aircraft were looked at, and two groups were identified amongst twin engined helicopters, which fitted linear regression lines for speed and direct operating costs: "sleek" (e.g. Dauphin) and "blunt" (e.g. BK 117). A weakness is that cabin ergonomics and patient capacity are not considered in the aircraft analysis, but this may be factored in elsewhere.

A stochastic simulation model was used to generate patient conditions and locations, with calculated probabilities of dying with and without basic and advanced life support and definitive care, per unit time. The model predicted, that an additional \$(C)100 outlay on DOCs per flight (i.e. faster more expensive aircraft) improved patient survival probabilities, *but that the improvement ranged from 1 to 30% depending on the efficacy of the procedures able to be administered by the medical flight crew, the overall coefficient of clinical care ("theta")*. Cabin ergonomics and the overall medical suitability of the aircraft can be factored into this.

This conclusion appears to be that clinical care is more important than speed. This is consistent with several papers by Baxt and Moody (8-10), and Moylan and co workers (11) suggesting improved survival in actual patients with more advanced clinical care.

We can to some extent tie all these different models together in a simplistic fashion in what Dr. Beehan and I call the "donut" model. Within a certain distance of a facility, there will be an area

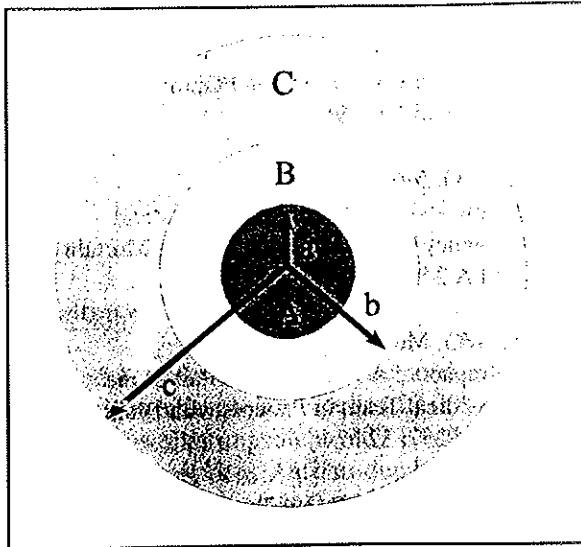


Figure 3:  
"Donut" area model for air medical services

too close for the air medical service to be of relevance. Beyond this is ring "B" within which an air medical service can benefit a proportion of patients, by delivery of critical care to the scene faster than by taking them to hospital by alternative transport. This is only applicable if the coefficient of clinical care is higher than provided by the alternative transport. The economic question as outlined in the Bruhn study is relevant here: as to whether to provide this ring by air or by more advanced ground services.

Beyond ring "B" is ring "C" within which air transport always offers a time advantage. The outer limit of "C" will depend to some extent on the abutment of other services, but there may also be a ring "D" where a proportion of patients may benefit from care delivered to them, even if delivery to that base hospital is no longer practical. Coefficient of clinical care again becomes important in this zone.

An equation can then be developed which looks at the portion of the target population, which is served by the air medical program, which factors in a coefficient of clinical care "X". This coefficient lies between 0 and 1, where 0 represents no difference in clinical care between ground and air teams and 1 is where total hospital level care is provided by the air medical team. Factors influencing "X" include the clinical skills of the air medical team, the equipment and stores

carried, and also the ergonomics of the aircraft cabin for the delivery of medical care. The value of "X" will vary for different patients, but a mean value of "X" can be calculated and used as a predictor.

The number of patients potentially benefitting from an air medical service in this model can be given by the equation

$$b^2 - a^2 + X \cdot (c^2 - b^2)$$

all multiplied by the population density.

Finally, if we improve outcome, what is the value of this? No review of models would be complete without the studies of Baum and co-workers carried out here in Germany on the total costs and benefits of the air rescue system (12, 13). These costs can be broken down into health service costs and benefits; and wider economic costs and benefits.

Within the health service sphere, trauma patients who were treated and transported by a physician staffed helicopter had reduced complications and reduced ICU bed stays compared with similar patients transported by ground ambulance. It was estimated that each air medical unit needed to keep only a single young adult out of long term institutional care per year to pay its way in terms of total health expenditure.

In terms of the wider economic model, an analysis was developed of total benefits of patients returned to normal existence, factoring in contribution to gross national product, taxes paid, dependants supported. This analysis calculates, that the air rescue service makes a significant positive contribution to the German economy, in fact exceeding that accruing from the use of seatbelts. It may not be necessary to demonstrate economic benefit for all aspects of air medical practice. Air medical services often function as a health care integrator, or resource multiplier – putting a wider range of services within practical reach of a larger number of people than would otherwise be practical (14).

If a service is provided to some parts of the population by or at the behest of government, then the principles of equity and fairness demand that these be available to all. Air medical services may be the only practical option.

So, can we develop a unified model? It must cover all aspects: population, time, clinical care, outcome, cost, and overall benefits. It should be inclusive of the whole spectrum of air medical practice and it must be of predictive value. If such a model can be developed, it can be used to design or redesign air medical services, and to serve as a rationale for their adoption.

A model as described, can then be an invaluable foundation for the creation of realistic standards: for aircraft specifications, clinical care, medical equipment, operations and communications, training and quality assurance. Such a model and associated standards can form a living document, continuously upgraded to respond to changes in technology and medical knowledge.

In conclusion, the development of a valid widely applicable scientific model of air medical practice is one of the major challenges facing the air medical profession.

#### References

1. McNab AJ (1992).  
"Hot Air" and a French Lesson.  
J Air Med Transport 11: 15.
2. Munford BJ, Beehan SJ, Bishop RO (1994).  
Population Model of Air Medical Services.  
Submission to Australian Health Ministers  
Advisory Council Report on Air Medical  
Services.
3. Fischer RP, et al. (1984).  
Urban Helicopter Response to the Scene of  
Injury.  
J Trauma 24: 196.
4. Smith JS, Smith BJ, et al. (1993).  
When is Air Medical Service Faster than Ground  
Transport?  
J Air Med Transport 12: 258.
5. Bruhn JD, Williams KA, Aghababian R (1993).  
True Costs of Air Medical vs Ground Ambulance  
Systems. J Air Med Transport 12: 262.
6. Schiller WR, et al. (1988).  
Effect of Helicopter Transport of Trauma Victims  
on Survival at an Urban Trauma Center.  
J Trauma 28: 1127.
7. Stundzia AB, Lumsden CJ (1994).  
A Computer Based Simulator for Air Ambulance  
System Analysis, Design and Optimisation.  
Air Medical J 13: 96.
8. Baxt WG, Moody P (1983).  
The Impact of a Rotorcraft Aeromedical  
Emergency Care Service on Trauma Mortality.  
J A M A 249: 3047
9. Baxt WG, Moody P (1987a).  
The Impact of A Physician As Part of the  
Aeromedical Team in Patients with Blunt Trauma.  
J A M A 257: 3246
10. Baxt WG, Moody P (1987b).  
The Impact of Advanced Prehospital Emergency  
Care on the Mortality of Severely Brain Injured  
Patients.  
J Trauma 27: 365.
11. Moylan J, Fitzpatrick DT, et al. (1986).  
Factors Improving Survival in Multisystem  
Trauma Patients.  
Ann Surg 207: 679
12. Oestern, HG (1985).  
The German Model for the Rescue of  
Traumatised Patients.  
Can J Surg 28: 486.
13. Baum H, Kugler G (1993).  
Cost Benefit Analysis for the Medical Helicopter  
Service in Germany – An Evaluation of Primary  
Intervention Flights and Secondary Transfer  
Flights. (Presented at) AIRMED '93, Fourth  
Congress of International Society of Aeromedical  
Services, Sydney, Australia.
14. Association of Air Medical Services (1994).  
Air Medical Systems as a Health Care Integrator.  
Air Medical J 13: 405.

#### Authors

*"Development of a Model for Air Medical  
Service Utilisation"*  
Sean J. Beehan, MB, ChB, FANZCA,  
Medical Director  
Blair J. Munford, MB, ChB, BMedSci, FANZCA,  
Deputy Medical Director  
NRMA CareFlight/NSW Medical Retrieval Service  
Sydney, Australia