Triage and emergency evacuation of recreational divers: A case series analysis

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ABSTRACT

Introduction: It is unknown if the benefits of rapid treatment always outweigh the risks of emergency evacuation for recreational divers. To investigate current triage practice, we reviewed a three-year consecutive series of evacuations and analyzed the relationship of evacuation completion time (EvCT) to outcome in the decompression illness (DCI) cases.

Methods: Checkbox-keyword searches of calls to Divers Alert Network (DAN) between 4/06 and 2/09 identified cases for review.

Results: Of 24,275 calls, 107 were evacuations. Median EvCT, (defined as time from injury to arrival at treatment facility) was 20 hours (mean ± SD, 27.3 ± 27.2). Indications were: DCI 56% (60), medical illness 28% (30) or trauma 16% (17). Twenty-five percent of medically indicated evacuations were for pre-existing conditions. One-third of all DCI air evacuations (17 of 51) were for mild cases (pain or tingling only). EvCT and presentation severity were not significant predictors of DCI outcome; however, early data (< 6 hours) was sparse.

Conclusion: More data are needed assess the benefits of faster evacuations. However, in real-world scenarios with EvCTs in the 20-hour range, time did not influence outcome. Risk-benefit analysis of emergency transport is advised, especially for mild cases of DCI with a low probability of symptom progression.

INTRODUCTION

Medical infrastructure at many remote dive sites is underdeveloped, and as more recreational divers travel farther afield, the need for emergency evacuations has increased. While most evacuations are carried out safely and efficiently, no travel is risk-free, and emergency medical transport carries a surprisingly high crash risk. Even in developed countries, emergency medical service workers experience twice the national average of occupational fatalities; 75% of these are transport-related (1), and the risk is shared by workers, patients and uninvolved bystanders alike (2-6, 7). These statistics spotlight the importance of transport risk to medical benefit calculations during evacuation triage.

Emergency evacuations are intended to decrease time-to-treatment intervals. Standard references recommend prompt recompression of decompression sickness (DCS) (8-10), and U.S. Navy policy allows no-ascent training, a procedure with a risk of arterial gas emboli, unless a recompression chamber is available within 10 minutes' travel time (11). Most military and commercial diving has readily available recompression support. However, recreational divers may not have the luxury of a nearby recompression chamber and injury-to-treatment times are more likely to be hours or days rather than minutes. Although a shorter time to treatment is traditionally thought to be better, once injury-to-recompression

time exceeds an unknown limit or "golden hour(s)", the relation of time to treatment and post-recompression outcome is less well understood (12). This implies that higher- risk transport modalities may provide little additional benefit after a long initial delay. In addition, the importance of time to treatment for DCI may be modified by case severity. After a finite period of time, stable mild symptoms rarely progress (13,14), a finding that led the 2004 international symposium on the Management of Mild or Marginal Decompression Illness in Remote Locations Workshop to conclude that delays in the treatment of mild or marginal DCI are unlikely to adversely affect outcome (15). Therefore, in an attempt to improve our understanding of current triage and evacuation practices for recreational divers, we compiled a consecutive sample of evacuation cases from the DAN Diving Emergency Hotline database that were stratified by indication, latency and severity and compared their immediate outcomes after treatment.

MATERIALS AND METHODS

Data collection and time calculation

The U.S. office of Divers Alert Network maintains a 24-hour Diving Emergency Hotline that is accessible worldwide. Since April of 2006, all hotline calls have been logged into DAN's Medical Service Call Center (MSCC) database. In 2008 a Duke University IRB exemption allowed the research use of a de-identified copy of the database to compile a sequential series of evacuation-related records identified by a specific check-box and keyword search from the records entered between April 1, 2006, and February 28, 2009.

Each evacuation case record and available follow-up notes were individually reviewed. If more than one medical evacuation was required (*e.g.*, transport to a local facility followed by transfer to a regional facility for rehabilitation) the first evacuation was used for data collection. Repatriations (transport solely for the purpose of returning home) and transport of mortal remains were excluded.

Data collected were: patient demographics, evacuation indication, a binary estimate of case severity (DCI cases only), critical times, mode of transport, geographic location of the initiating incident, distance traveled, number of HBO_2 treatments (DCI cases only), and outcome immediately after the last treatment (DCI cases only). DCI severity was stratified by the case's presenting symptoms into two categories:

1) serious neurological DCI, defined as any case with motor, special sensory (smell, sight, taste, hearing, and equilibrium) or cortical manifestations; or
2) mild DCI, defined as cases limited to pain, paresthesias or skin symptoms.

Non-DCI cases were included for comparison basis only and were classified by their indications as traumatic or medical. Non-DCI outcomes were not classified because of the high variability of the underlying prognosis associated with their indications. Three critical time periods were recorded:

1) symptom to call, defined as the time from accident or first medical symptom to the hotline call;
2) call to end of evacuation, defined as the time from hotline call to the patient's arrival at the evacuation destination; and
3) evacuation completion time (EvCT), defined as the sum of the two times listed above.

For DCI cases, the time from the end of the last dive to the first symptom was recorded and the end of the last dive was taken as the time of injury and included in the EvCT.

If not otherwise stated, evacuations were assumed to be medically indicated, and treatment was assumed to commence immediately upon arrival at the evacuation destination. The mode of transport was categorized as land, sea, or air. Locations where the evacuations originated were grouped by region:

1) Canada and the continental U.S.;
2) the Caribbean;
3) Mexico and Central America;
4) South America (including Galapagos);
5) South Pacific (including Hawaii, Australia, New Zealand and Papua New Guinea);
6) Asia Pacific (including the Indonesian half of New Guinea); or
7) Africa.

FIGURE 1

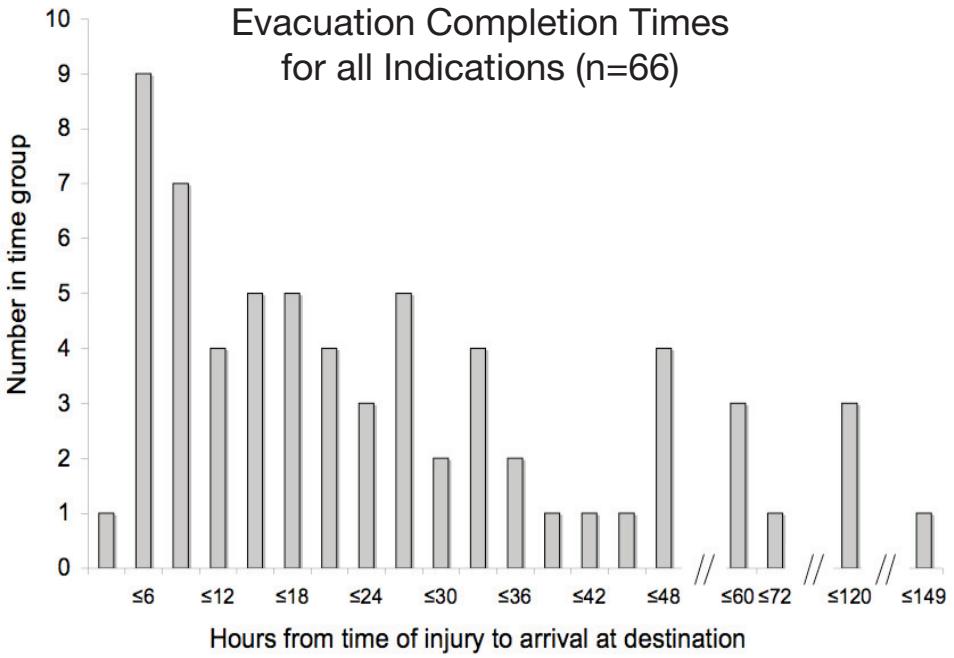

Figure 1. Evacuation distances varied by region and indication. Table 1 *(Page 136)* shows the number of cases logged from each region and the mean distances traveled. Table 2 *(Page 136)* shows mean distances and the median EvCTs by indications.

Straight-line evacuation distances were estimated using Google Earth. DCI outcomes were determined by reviewing all available clinical entries including symptom status checkboxes and the narrative reports in the database. Possible outcomes were: 1) resolved; 2) incompletely resolved; 3) unchanged; or 4)worse. The Pearson chi-square test was used to assess the independence of categorical variables, the Kruskal-Wallis test was used to assess non-normally distributed parameters (symptom onset time, symptom-to-call time, EvCT), and logistic regression was used to assess the association of EvCT with DCI symptom resolution while controlling for case presentation severity. Median values were preferentially reported for non-normally distributed values. Independent, normally distributed parameters (age, distance) were compared by ANOVA with Tukey's HSD Post-Hoc analysis. When data was missing, cases were excluded on an analysis-by-analysis basis, not listwise. Statistical calculations were conducted using SPSS v8.0, and *p*-values of 0.05 were considered significant.

RESULTS

Sample characteristics

Between April 1, 2006 and February 28, 2009, a total of 24,275 calls were received, of which 7,245 were emergency calls, 267 involved medical transport and 107 met the inclusion criteria. The age and gender ratios of the 60 DCI cases mirrored the expected population of injured recreational divers (16). In trauma-related evacuations, females predominated, and the medically evacuated population was more than one decade older than those evacuated for DCI (p=.01 ANOVA). Twenty-five percent of all evacuations for medical indications were related to a pre-existing condition (8 of 30).

Evacuation distances and times

There were 66 cases with sufficient data to calculate EvCTs in the sample. For all indications, the EvCT values were right-skewed, with values ranging from less than two hours to more than six days. The median EvCT was 20.25 hours (*Figure 1*, above). For DCI cases only, the times were similarly

TABLE 1

Distance and count of each indication for evacuation by region

	Trauma	Medical Illness	DCI	Distance (range km)
Africa			1	305
Asia-Pacific	1	3	3	1804 (15-4641)
Canada, U.S.	1	3	14	218 (55-881)
Caribbean	3	16	27	384 (22-1993)
Mexico, Central America	10	3	7	1264 (468-2905)
Australia, NZ, S. Pacific	1	4	8	804 (250-1313)
South America	1	1		1167

TABLE 2

Distance and EvCT by indications for evacuation

	N	Distance (mean km, range)	Median EvCT hours (range km)
Trauma	13	1503 (250-4641	18.2 (13-21)
Medical illness	26	869 (22-2830)	36 (4-148)
DCI	52	376 (15-1680)*	16 (1.7-67)
Missing	13		

* the mean evacuation distance for DCI cases was less than for other indications by ANOVA with Tukey's HSD Post-Hoc analysis p=.001, median EvCT was greater for medical indications by Kruskal-Wallis p=.03.

right-skewed with a median EvCT of 16 hours and a range of 1.7 to 67 hours.

Out of 60 DCI cases, there were 48 cases with both severity and EvCT data available. The median symptom onset-to-call time was significantly less for divers with serious presenting symptoms at 1.5 hours compared with 7.2 hours than for those with mild symptoms (p=.03 Kruskal-Wallis). Median symptom onset times for serious and mild DCI presentations were five and ten minutes respectively. The median EvCT for all 48 DCI cases was 16 hours, and 60 percent of divers presenting with severe symptoms were evacuated in less than that amount of time. There was no association of DCI severity with the type of transport (air versus other) selected. Air evacuations predominated for DCI cases (39 fixed-wing, eight helicopter, three ground and one boat), and one-third of all air evacuations for DCI (17 of 48) were for cases without serious neurological symptoms.

Treatments

Forty-eight cases had data on both severity and treatment numbers. The numbers of HBO_2 treatments ranged from one to 56; however, the median number of treatments was one for cases that resolved and four for those that did not. The number of treatments was positively associated with longer EvCTs (p=.01) and serious presenting symptoms (p=.04) when analyzed by linear regression.

Outcomes

There were 48 cases with both outcome and presentation severity data available. Univariable analysis showed that 54% of mild cases resolved

FIGURE 2

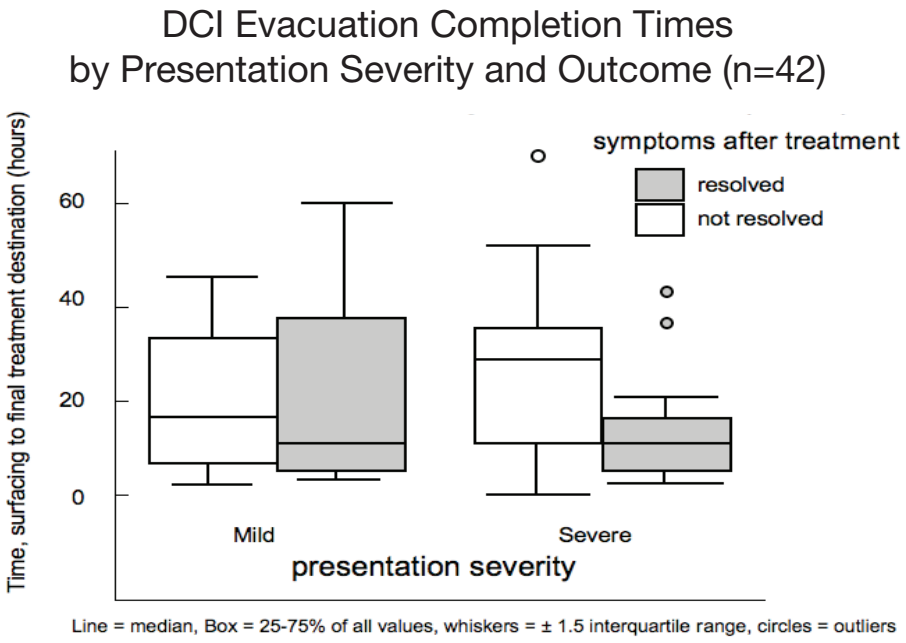

Figure 2. DCI evacuation completion times by resolution status and severity.

completely after the first treatment, compared with only 39.4% of cases with serious neurological findings (p=.029 chi square). There were 42 DCI cases with severity, time and outcome data points available. Evacuation completion time alone was not a significant predictor of resolution (p=.064 chi square). When EvCT and presentation severity were considered together using logistic regression, neither time (p=.148) nor severity (p=.165) predicted symptom resolution. A box-plot of EvCTs stratified by severity of presenting symptoms and resolution after treatment is shown in Figure 2, *(above)*.

Of the 48 DCI cases with known outcomes, 24/48 (50%) had resolved completely by the time of follow-up, 23/42 (48%) were improved, and one case had worsened. There was one diving-related death from a presumed arterial gas embolism in this sample. There were no deaths attributed to DCS.

DISCUSSION

As the number of recreational dive trips to remote sites has increased, evacuations for all causes have become more common. This sample is a cross-sectional analysis of a population that exhibits that trend. The overall median EvCT for all indications was 20.25 hours and was significantly greater (p=.03) for medical illness (36 hours) than for DCI (16 hours) or trauma (18 hours). Travelers evacuated for non-diving medical indications were older and 25% of them were transported for pre-existing conditions suggesting that the risk profile is shifting towards that of an older population along with the change in diver demographics. Time-to-call as well as EvCTs were related to distance, region and severity as would be expected. Treatment numbers were related to severity but also to EvCT. However, EvCT was unable to significantly predict clinical outcome when the severity of the presenting symptoms was controlled for. Although this finding agrees with other studies (12,17), it may be a consequence of the size and quality of the samples. The clinical experience of the authors leads us to believe that a beneficial effect of early treatment may be hidden in a non-linear relationship between EvCT and outcome for serious neurological DCI and that this relationship may not be evident without larger numbers of cases with shorter

(<six-hour) EvCTs. When total EvCT was converted to a binary variable by splitting the cases at the median (≤16 hours), the < 16-hour EvCT group had 3.4 times the odds of resolution compared to the ≥ 16-hour group with a *p*-value that approached statistical significance (p=0.068). This finding suggests the possibility of a non-linear relationship between EvCT and outcome in DCI cases fitting our definition of serious neurological presenting symptoms. In addition, DCI that resolved after treatment was non-significantly (p=.068) associated with shorter EvCTs when severity of presentation was controlled for by logistic regression. Finally, there was a correlation between EvCT and number of treatments which, taken together, suggest a possible and clinically appealing benefit for rapid transport and early treatment of serious cases of DCI. This supposition will require further study using data with more observations in earlier time periods if it is to be proven.

The present study was limited in that only five of the cases with serious neurological symptoms had EvCTs of less than six hours, and this number was not sufficient to detect a beneficial clinical effect related to the six-hour time-to-treatment frame recommended by Stipp (10). However, for cases of mild DCI, the converse of an early treatment effect may be detectable in our sample. The finding that divers with mild DCI did not show any less benefit from later treatment when the sample was divided at the 16-hour median time strongly argues that severity of symptom presentation, along with the transport-related risk factors such as visibility, weather and scheduled versus unscheduled flights, are important triage considerations that could decrease transport risk to the diver without adversely affecting outcome in mild DCI cases. Other studies have arrived at similar conclusions (12,15,17,18). Moreover, the low probability of DCI symptom progression after six hours of stability (13,14,18) is an important consideration when a risky evacuation is contemplated. The finding that one-third of all air evacuations for DCI in our sample were for cases without serious neurological symptoms indicates that current triage practice may not always properly balance evacuation risk and benefits in mild cases of DCI.

Many criticisms of a retrospective study of this type are possible, but the available data allowed comparisons of initial symptoms, outcome and transport latencies in a way not previously seen. Unfortunately, specific reasons justifying individual decisions to evacuate were not recorded in the database. This information is important and should be collected for future studies. Other shortcomings are that the numbers are small, they may represent incompletely the actual number of evacuations arising from hotline calls, the diagnoses were unconfirmed, and follow-up was incomplete, leading to not all outcomes being known. Furthermore, it should be accepted that these data come from recreational divers and cannot be generalized to indigenous, military and commercial diving populations with their distinct diving methods, means of treatment and procedures for medical evacuation.

In summary, DCI cases caused the majority of evacuations for callers to the DAN Hotline. Higher resolution data is needed for EvCTs of less than six hours to avoid a Type 2 error that improperly rejects a beneficial effect of prompt evacuation and treatment for cases with serious neurological presenting symptoms. However, in current real-world DCI evacuations where the median injury-to-arrival time is 16 hours, medical outcomes are independent of EvCT for recreational divers. This argues that a careful risk-benefit analysis that takes into account the non-medical risks of urgent evacuations is warranted, especially for DCI patients with mild symptoms where transport logistics imply unavoidably longer delays.

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REFERENCES

1. Maguire BJ, Hunting KL, Smith GS, Levick NR. Occupational fatalities in emergency medical services: a hidden crisis. Annals of emergency medicine. 2002 Dec;40(6):625-32.

2. Kahn CA, Pirrallo RG, Kuhn EM. Characteristics of fatal ambulance crashes in the United States: an 11-year retrospective analysis. Prehosp Emerg Care. 2001 Jul-Sep;5(3):261-9.

3. Slattery DE, Silver A. The hazards of providing care in emergency vehicles: an opportunity for reform. Prehosp Emerg Care. 2009 Jul-Sep;13(3):388-97.

4. Baker SP, Grabowski JG, Dodd RS, Shanahan DF, Lamb MW, Li GH. EMS helicopter crashes: what influences fatal outcome? Annals of emergency medicine. 2006 Apr;47(4):351-6.

5. Holland J, Cooksley DG. Safety of helicopter aeromedical transport in Australia: a retrospective study. The Medical journal of Australia. 2005 Jan 3;182(1):17-9.

6. Williams DM, Zalar CM. The risky side of response. Increasing fatalities underscore the need for reconciled safety practices of ground & air ambulances. Jems. 2007 Apr;32(4):58, 60-4, 7.

7. Pasztor A. Study Spotlights Helicopter Dangers. Wall Street Journal. 2009 2/3/2009.

8. Moon RE, Sheffield PJ. Guidelines for treatment of decompression illness. Aviation, space, and environmental medicine. 1997;68(3):234-43.

9. Bove AA, Davis JC. Bove and Davis' Diving medicine. 4th ed. Philadelphia: W.B. Saunders 2004.

10. Stipp W. Time to treatment for decompression illness. Report to North Sea Medical Centre for the Health and Safety Executive. RR550. HSE Books. 2007.

11. United States Navy. U.S. Navy Diving Manual. Diving Medicine and Recompression Chamber Operations. Revision 6. Volume 2. U.S. Government Printing Office, Washington, D.C. 20402. Naval Sea Systems Command 2008.

12. Ross J, Sayer M, Trevett A, Wilson C. The relationship between time to recompression treatment and clinical outcome for decompression illness treated in Scotland. Undersea Hyperb Med. 2007;43(4):269.

13. Francis TJ, Pearson RR, Robertson AG, Hodgson M, Dutka AJ, Flynn ET. Central nervous system decompression sickness: latency of 1070 human cases. Undersea Biomed Res. 1988 Nov;15(6):403-17.

14. Francis TJ, Dutka AJ, Flynn ET. Experimental determination of latency, severity, and outcome in CNS decompression sickness. Undersea Biomed Res. 1988 Nov;15(6):419-27.

15. Mitchell SJ, Doolette DJ, Wacholz CJ, Vann RD. Consensus Statement. In: Network DA, editor. Management of Mild or Marginal Decompression Illness in Remote Locations Workshop; 2005; Sydney: Divers Alert Network; 2005.

16. Pollock NW, Vann RD, Denoble PJ, Freiberger JJ, Dovenbarger JA, Nord DA, et al. Annual Diving Report. Annual Diving Report. Divers Alert Network. 2007

17. Ross J. Clinical audit and outcome measures in the treatment of decompression illness in Scotland. A report to the National Health Service in Scotland Common Services Agency, National Services Division on the conduct and outcome of treatment for decompression illness in Scotland from 1991-1999. Department of Environmental and Occupational Medicine. University of Aberdeen Medical School. 2000

18. Ross J, Watt S. The relationship between the severity of decompression illness and symptom latency. Undersea Hyperb Med. 2001;28(2):70.

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