Transportation of divers with decompression illness on the west coast of Scotland

Colin M Wilson and Martin DJ Sayer

Key words
Decompression illness, decompression sickness, transport, recompression, clinical audit

Abstract
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Introduction: There is a time line for divers who develop decompression illnesses (DCI) from the completion of their dive to the initiation of recompression. The time to treatment is influenced by many factors; two being the time before acknowledgement that the diver has a pressure-related illness and the time taken for transfer from that point to commencment of recompression.
Method: Time to onset of symptoms, and time from onset of symptoms to treatment were analysed for 233 divers, 202 recreational and 31 professional, presenting within 24 h of onset of symptoms to the Dunstaffnage Hyperbaric Unit between 1990 and 2009, who were transported by air, sea or road.
Results: Divers with severe DCI had significantly shorter times for onset of symptoms (95% confidence intervals 0.9 to 2.3 h longer for mild/moderate compared to severe DCI) and were transferred for treatment approximately twice as fast as those with mild/moderate symptoms (inter-quartile ranges: recreational divers, 2.25–5.63 h for mild/moderate DCI versus 1.54–3.25 h for severe DCI; professional divers, 2.63–11.13 h for mild/moderate DCI versus 2.25–2.92 h for severe DCI). Although choice of transport was most likely influenced both by location and disease severity, transfer modality did not significantly affect time to treatment for divers with severe DCI. In addition, no differences in time to treatment were observed between professional and recreational divers irrespective of disease severity.
Conclusions: The data suggest that transport was optimised to fit the particular circumstances of the patient and that divers treated for DCI in Scotland may benefit from there being a single, integrated, co-ordinated clinical service.

Introduction

A number of challenges exist when considering any temporal element during the triage of divers with decompression illness (DCI). General opinion is that decompression illness should be treated as rapidly as possible, although the basis for determining the most favourable transfer time to a compression chamber is not apparent.[1] Severe decompression illness can be life-threatening because of neurological and cardio-pulmonary injury and is associated with hypovolaemic shock.[2–5] While some studies indicate a relationship between time to treatment and clinical outcome in decompression illness, others relate outcome to severity of the initial condition rather than delayed recompression.[6–13] In making assessments of any effects and/or benefits of the method of patient transport and the concomitant delay in treatment, there is a raft of factors that could influence decision making, such as the location of the most appropriate treatment facility, severity of symptoms, transport costs, transport safety, transfer time and infrastructure costs.[1,14,15]

The vast majority of diving worldwide probably relies on recompression facilities that are located some distance from the diving operations. Each location will differ markedly both in the type and the quality of the available transport infrastructure at the regional level but also in the capability of the emergency framework that is available to support patient transport. Invariably some of the transfer decisions will be dictated by cost, which, in turn, will be influenced by the severity of the diver's condition. Patient transfer is a significant component of the whole treatment pathway but is rarely studied.[15,16] The present account reports on an examination of transport data collated by one treatment centre in relation to severity of symptoms.

The catchment area for the Dunstaffnage Hyperbaric Unit, near Oban, covers most of the west coast of Scotland. The west coast is predominantly fjordic in nature, with numerous isolated peninsulas, isthmuses and inshore and offshore islands.[17] Road and rail infrastructure is limited or discontinuous in much of the region making land transportation difficult in many cases. The diving population on the west coast is predominantly recreational and boat-based. There are also a significant number of occupational divers employed in mariculture and shellfish industries. Many of the better recreational diving locations, the epicentres of the fish farming industry in Scotland and the most productive shellfish sites are in relatively remote locations.

Treatment of divers presenting with DCI in Scotland is provided by a single, co-ordinated clinical service.[18] The vast majority of cases are initially processed through a single telephone helpline provided at the consultant level by the hyperbaric facility at Aberdeen. Through discussions with the divers, local medics and/or the emergency services,

the Aberdeen doctor will advise on the most appropriate treatment pathway in terms both of which recompression chamber the patient should be taken to and the best form of transport to use. An exception to this is a relatively small proportion of divers that self-present, either at a local hospital or at the recompression facility itself.

The present study investigates the transfer modality in three distinct groups of presenting divers. Following the onset of recognisable symptoms of DCI, divers who have made it ashore tended to travel to the unit by road, either by private vehicle or ambulance. Divers who were still at sea, and within a reasonable distance from the unit, were transferred by lifeboat (operated by the Royal National Lifeboat Institute[19]), the vessel they had been diving from, or a combination of the two. Cases from further afield were usually transported by air when it was the only practical method dictated by the geographical position of the diver. Air transportation was either from the search and rescue organisations (military or coastguard) or air ambulance services (helicopter or fixed-wing).

Methods

The present study adheres to the procedures of implied consent operated by the UK National Health Service (NHS) for clinical audit. A total of 233 cases presenting within 24 hours (h) of onset of symptoms to the Dunstaffnage Hyperbaric Unit within the 20-year period 1990 to 2009 inclusive were analysed. All data were based on the information contained within the clinical record; all but three were first examined by one of a total of six physicians from a single practice employing a standard *pro-forma* record. Twenty-two other patients were omitted from the analyses if no information on transportation modality had been entered into the patient record (n = 5) or if the time from onset of symptoms to treatment exceeded 24 hours (n = 17).

The patient population was initially examined for basic demographics (sex and age) and the number of recreational divers. Cases were then assessed for symptom latency (time from surfacing to the onset of symptoms) and transfer time (time from onset of symptoms to start of treatment). Transfer time did not allow for differences between patients transported directly to the hyperbaric unit against those presenting via the hospital Accident and Emergency Department. Cases were analysed in two groups depending on the severity of their condition, based on previously published criteria: mild/moderate was no symptoms, pain only or sensory; severe was ataxia, motor involvement, nausea or vertigo, or cerebral symptoms and signs.[18] The severity groups were subdivided into their transport modality: land, sea or air. Time from onset of symptoms to treatment and number of patients were analysed by transfer modality, regional location and severity of presentation; professional status was analysed against transfer time for both of the DCI severity criteria. Statistical analysis followed preliminary examination for normality using modified (Lilliefors) Kolmogorov-Smirnov tests with transformation where necessary.[20–22]

Results

The proportion of recreational divers in the two main subsets was 85–89% (Table 1). Divers classified as having

Table 1
Transport type, demographics, diving type, symptom latency and time to treatment in 233 cases of decompression illness presenting within 24 h of onset of symptoms to the Dunstaffnage Hyperbaric Unit (1990-2009)

	Severe DCI				Mild/moderate DCI			
	Overall	**Land**	**Sea**	**Air**	**Overall**	**Land**	**Sea**	**Air**
Number of divers	65	19	29	17	167–168	67–68	54	46
Males (%)	86	89	86	83	80	81	80	80
Age (y)								
Mean	40.4	41.4	40.1	39.8	34.9	33.9	35.2	36.0
Median	39	39	39	36	33	32	34	34
Range	20–62	22–62	20–61	27–58	16–77	18–59	16–77	20–61
Recreational (%)	89	95	89	83	85	82	85	78
Time to onset of symptoms								
Mean	0.36	0.22	0.38	0.49	1.99	3.24	1.29	0.99
Median	0.17	0.08	0.17	0.17	0.33	0.50	0.29	0.25
IQ range	0–0.33	0–0.21	0.05–0.33	0.08–0.41	0.17–1.34	0.25–2.0	0.17–1.34	0.10–1.0
Range	0–3.5	0–2.0	0–2.5	0–3.5	0–24	0–24	0–19	0–13
Time from onset to treatment								
Mean	2.96	2.86	2.97	3.04	5.65	6.44	4.78	5.54
Median	2.0	2.0	2.0	2.92	3.08	3.88	3.08	4.0
IQ range	1.75–3.25	1.5–2.63	1.75–3.25	2–3.25	2.25–6	2.25–6.48	2.25–6	2.75–5.88
Range	0.67–12.75	0.83–12.75	0.67–12.0	1.75–7.0	0.25–22.5	0.25–22.3	0.58–20.0	0.83–22.5

severe DCI were significantly older than those in the mild/moderate group (*Z*-test following log transformations, $P < 0.05$; 95% confidence intervals (CI) +1.1 to +1.3 y); there was no significant difference for sex ratio between the two groups (Z-test, $P > 0.05$) (Table 1).

In total, air transfer was used in 27% of the cases examined, transfer by sea occurred in 36% and land transport in 37% of cases. Sea transport was the most common method of transfer for severe cases; land transport was the most common for mild/moderate cases. The proportion of transfers conducted by each of the three transport methods examined did not differ significantly with the two severities of condition (*Z*-test, $P > 0.05$ in all cases).

Time from the onset of symptoms to treatment was analysed by professional status for both DCI severity groups (Table 2). In general, professional divers took longer than recreational divers to receive treatment for mild to moderate presentations, and shorter for severe cases; however, both relationships were not significant (t-test, $P > 0.05$ in both cases).

A map of Scotland laying out the main diving areas, transport infrastructure and recompression facilities is shown in Figure 1. Comparing transport modality with location illustrates some of the drivers of the decision process (Table 3). With reasonable road and sea (lifeboat plus divers' own boats) links, and the relative distance from helicopter support, the main methods for patient transfer in the Oban area are land and sea for all types of DCI (Table 3). There was no clear transport of choice for the Inner Hebrides, irrespective of severity of presentation, and this probably reflects the variation in proximity to short ferry times, boat rides and lifeboat transfers for these islands. Not surprisingly, where the only non-emergency transport available from the Outer Isles to the mainland is by scheduled ferries, all Outer Hebrides transfers were by air (helicopter in all but one which was a fixed-wing transfer). This may also have been influenced by the availability of an emergency helicopter based at Stornoway (St; Figure 1). Road and rail links between Skye and Oban are generally poor, and the location of the Skye area midway between the helicopter based at Stornoway and the Oban facility makes air transfer a more logical choice of transport (Table 3). The transfer modality and transport times from the southern sea lochs reflect a large variation in the quality of communication links (but not necessarily straight-line distances) to Oban in addition to the closer proximity to the Prestwick helicopter base (Pr; Figure 1).

Table 2
Time from onset of symptoms to treatment (minutes) in relation to professional status and severity of presentation for 233 cases of decompression illness presenting within 24 h of onset of symptoms to the Dunstaffnage Hyperbaric Unit (1990-2009)

	Recreational		Professional	
	Mild/mod	Severe	Mild/mod	Severe
Number	144	58	24	7
Mean	5.34	3.01	7.56	2.54
Median	3.42	2.00	4.59	2.67
I-Q range	2.25–5.63	1.54–3.25	2.63–11.13	2.25–2.92

Figure 1
Diagrammatic representation of the west coast of Scotland (shaded light grey; darker shading represents greater population density – west coast population density is 8–15 persons km^{-2}). Trunk roads are solid lines; railways are dashed lines. The Dunstaffnage Hyperbaric Unit is located just north of Oban (solid circular dot; Ob); Oban has three helicopter and one fixed-wing landing facilities. Two emergency helicopter bases exist, one at Stornoway (solid circular dot; St) and one at Prestwick (solid circular dot; Pr); one hour flight time radii for both bases are marked. Royal National Lifeboat Institute stations are marked as open squares. The Dunstaffnage facility provides an emergency recompression service for the whole of the west coast from the Mull of Kintyre (MK) in the south, to Cape Wrath (CW) in the north. Fish farm and shellfish diving occurs throughout the whole of the region but is concentrated in the Outer and Inner Hebrides (OH and IH, respectively). Centres of recreational diving activity are around Oban (Ob), the Sound of Mull (M), on and around the Isle of Skye (S) and the offshore islands of St Kilda (SK). Transport between the islands and the mainland is by ferry; the two main ferry hubs are at Oban (Ob) and Ullapool (U). Railway lines run inland from Oban and Fort William (FW); between Fort William and Mallaig (Ma); and between Inverness (IN) and Kyle of Lochalsh. (KL). Scale bar = 50 miles; inset is the Shetland Isles.

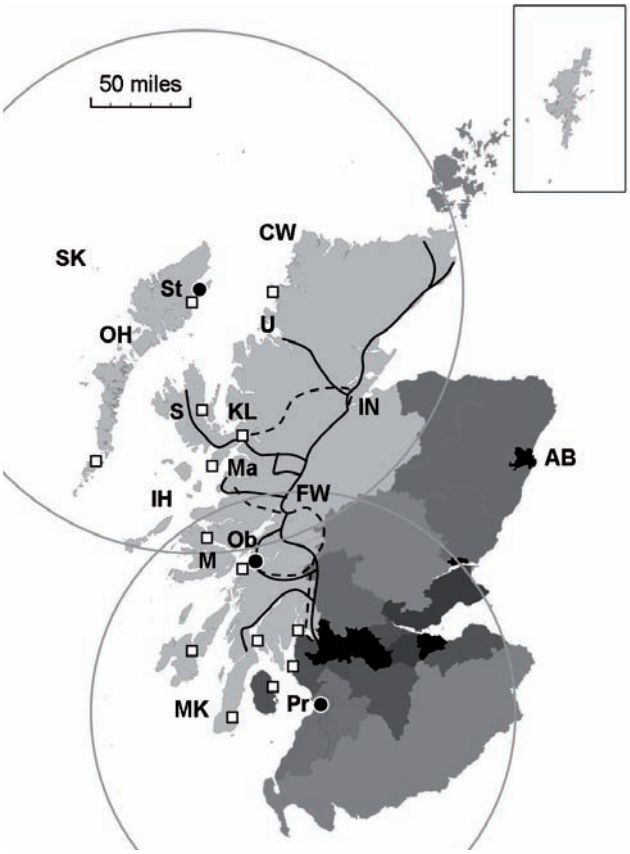

Table 3
Median time from onset of symptoms to treatment (h), transport modality (*n*, in parentheses) in relation to location (refer to Figure 1) and symptom severity for 233 cases of decompression illness presenting to the Dunstaffnage Hyperbaric Unit (1990–2009); spaces = no data

Location	Severe DCI			Mild/moderate DCI		
	Land	Sea	Air	Land	Sea	Air
Oban / Sound of Mull	1.63 (14)	2.00 (27)	2.46 (6)	3.50 (57)	3.00 (53)	2.46 (6)
Inner Hebrides	2.00 (1)	6.88 (2)	2.00 (3)	20.00 (3)	8.75 (1)	4.13 (4)
Outer Hebrides			3.25 (4)			4.33 (12)
Isle of Skye *	7.75 (2)		2.67 (3)	6.84 (2)		4.00 (20)
Southern sea lochs †	1.75 (2)		5.00 (1)	3.75 (7)		6.00 (3)
Other ‡				21.00 (1)		

* Includes mainland sea lochs to the north (Sutherland) and the south (Knoydart) of Skye
† Southern sea lochs refers to Lochs Fyne, Long, and the Firth of Clyde
‡ Case treated at Dunstaffnage but originating out of the area

Onset of symptoms was significantly more rapid in the severe group compared with mild/moderate cases (Mann-Whitney $P < 0.05$; 95% CI 0.9 to 2.3 h longer for mild/moderate; Table 1). The longest time for onset of symptoms was 3.5 h in the severe group and 24 h for the mild/moderate cases (although there were longer times than 24 h recorded for the mild/moderate group, these were outside the time limit considered in this study).

In severe DCI cases, transport type was not related significantly to symptom latency (Kruskal-Wallis test, $P > 0.05$); in mild/moderate cases, divers transferred by land had significantly longer symptom latency compared with air or sea transfers (Kruskal-Wallis test, $P < 0.05$).

In these data, it was not possible to distinguish the time following onset of symptoms from when there was acceptance of an issue, nor the time at which medical advice/help was requested during the total transportation process to a hyperbaric facility. However, overall time from symptom onset to treatment was significantly shorter for severe cases compared with mild/moderate ones (Mann-Whitney test, $P < 0.05$; 95% CI 1.7 – 3.7 h longer for mild/moderate; Table 1). There were no significant differences in transfer time between land, air and sea within both the severity groups (Kruskal-Wallis test, $P > 0.05$ in both cases).

Discussion

In the present study, once a diving-related problem was recognised, patients with severe symptoms were transported to the Oban recompression facility faster than those with mild-to-moderate symptoms, irrespective of the form of transport used. In the geographical region studied, there was a single NHS-registered treatment facility and rarely was there an even or open choice between the three transport modalities; transport type was more likely to be affected by the location of incident. For example, divers entering the emergency system on outer islands or peninsulas with no existing road infrastructure were more likely to be transported by air. The alternative solution would have been to rely on sea transfers that may have been beyond the operational range of some vessels or would have been affected by timetabled schedules, if relying on commercial ferries. Therefore, slower sea transfers were unlikely to be considered irrespective of issues related to perceived severity of condition, costs or risks.[15]

It may be the case that divers presenting with severe symptoms were more prevalent in the areas where there was actually a transport choice (e.g., the use of faster lifeboats or ambulances compared with the divers' own boat or car). Although the basis for the decisions about transport type was not recorded, the lack of any significant differences in transfer time for severe cases tends to suggest that an informed triage was adopted in order to optimise transfer time. However, the lack of difference is probably influenced greatly by there being a lack of any major choice in terms of the most appropriate chamber for treatment and/or the most appropriate modality of transfer. It is also unlikely that a diver with deteriorating severe DCI would be transferred any differently and/or more quickly than one with stable and/or improving severe DCI.

The integrated, single clinical service for emergency recompression in Scotland permits an initial transfer immediately to the more advanced clinical facility in Aberdeen. However, this has never happened for divers in the region described in the present study; critically ill patients have either received primary treatment at Oban before transfer to Aberdeen for additional treatment or have obtained initial stabilisation at the Oban Hospital, without recompression, before transfer to Aberdeen for their initial recompression treatment.

In the present study, cases of severe DCI had a more rapid

onset of symptoms. Indications of severe DCI in divers will usually be more distinctive than those of mild/moderate disease and so it is not surprising that there was a shorter time in recognising the problem in these cases. Consequently, there was a more rapid call for advice and transportation for treatment. This meant that 75% of the severe cases began their treatment in less than four hours from surfacing compared with approximately 7.3 hours for 75% of mild-to-moderate cases. Again, this indicates that a form of triage had been adopted whereby transport type and transfer time may have been considered to be less important for the mild to moderate cases. Even though the transfer modality may have been the same, mild/moderate cases were probably ranked in their importance for transfer: for example, air transfer times for mild-to-moderate cases were significantly longer than those for severe even though transport times, because of relatively short direct flight distances and fixed maximum speeds, would be expected not to differ (Table 1).

Professional status did not affect time to treatment. Delayed treatment could have been expected from the professional diving group because of a potential negative perception to how their future income may be affected. Time to treatment for the professional group presenting with mild-to-moderate symptoms was longer than that of recreational divers, but this was not statistically significant. While any delay could reflect a reluctance to seek treatment, it could also be influenced by location, with more professional divers being transferred from the Outer Isles.

There is a tendency to categorise the west coast of Scotland as the most remote location in the UK for transporting divers with DCI. However, median transfer times for west coast cases for both severe and mild-to-moderate DCI (2.00 and 3.88 h, respectively) are considerably shorter than those found in, for example, typical DAN data (20.25 h) or in the north-east coast of Australia (53.2 h).[15,23] The present study ignored cases where transfer was over 24 h (although this only occurred in mild-to-moderate cases) because the transfer infrastructure and distances involved would place all cases well within a 24 h transfer period. Therefore, transfers taking longer than 24 h were obvious outliers most often associated with denial or continued diving with DCI symptoms. Inclusion of these outliers would not have affected the overall trend that divers with DCI on the west coast of Scotland tend to be transferred relatively quickly to treatment facilities. This is mainly because transfer modalities are available to reduce the problems of a relatively remote and maritime-dominated coastline. As such, the issues related to the management of mild or marginal DCI in remote locations are largely irrelevant to incidents that occur in Scotland.[24]

Previous studies have shown that divers treated for DCI in Scottish facilities have a high rate of good clinical outcome.[25] Part of the reason for this may be that Scotland has an integrated transfer system that prioritises and optimises patient transport.

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Colin M Wilson, MB, ChB, FRCA, is the Medical Director of the Dunstaffnage Hyperbaric Unit, Oban, Argyll, Scotland. He is also a GP Anaesthetist at the Lorn Medical Centre and the Lorn and the Islands General District Hospital, Oban. He is currently Chair of the British Hyperbaric Association.
Martin DJ Sayer, BSc, PhD, FSUT, MAE, is Head of the Dunstaffnage Hyperbaric Unit hosted at the National Facility for Scientific Diving (NFSD) at the Scottish Association for Marine Science Laboratories, Oban. He is also Head of the NFSD and Technical Advisor for the Scottish Recompression Registration Service.

Address for correspondence:
Dr CM Wilson
Lorn Medical Centre,
Soroba Road
Oban, Argyll PA34 4HE,
Scotland
Phone: *+44-(0)1631-563175*
E-mail: *<colinwilson@tiscali.co.uk>*