Treating Decompression Sickness: Military Flight Simulation Site—Community Hospital Partnership

Whitney C. Rhodes, PhD, MSPA*; George Hertner, MD†; COL Robert Price, MC USA†‡§; Lani Finck, BA†; Claudia Temmer, MBA†; Tracy Cushing, MD, MPH*; Col Kathleen Flarity, USAF NC†‡¶

ABSTRACT  Background: High-altitude flight simulation familiarizes military trainees with the symptoms of hypoxia to prepare them for emergency situations. Decompression sickness (DCS) can occur as a result of these simulations. In cases when ground-level supplemental oxygen does not resolve symptoms, hyperbaric oxygen (HBO) therapy is indicated. Many military hyperbaric chambers have been closed because of cost reductions, necessitating partnerships with community hospitals to ensure access to treatment. Materials and Methods: This article describes the unique arrangement between a community hospital in Colorado and a military training site to treat DCS cases emergently. We gathered cost data from the community hospital to estimate and compare the cost of providing HBO therapy in the hospital versus a standalone chamber similar to the former military hyperbaric chamber. Results: Since the closure of the military hyperbaric chamber, the community hospital treated an estimated 50 patients with DCS requiring HBO therapy attributed to high-altitude flight simulation between October 2003 and April 2015. Cost to the institution providing HBO treatment varies widely on the basis of patient volume. Assuming a volume of five treatments, per-treatment cost at a standalone center is $95,380. In contrast, per-treatment cost at the hospital assuming a volume of 1,000 treatments commensurate with the hospital’s ability to bill for other services is $698 per treatment. Conclusion: The cost analysis demonstrates that the per-treatment cost of operating a standalone HBO therapy center may be greater than 100 times that of operating a center at a community hospital, suggesting the arrangement is beneficial to the military.

BACKGROUND
Military flight crew members and trainees require periodic familiarization and training in a flight altitude chamber. The altitude chamber is depressurized, which affords military trainees and flight crews the ability to recognize their personal signs and symptoms of hypoxia and other physiological changes associated with flight. Additionally, participants practice emergency procedures in a simulated rapid decompression: a high altitude in-flight emergency situation where a dramatic decrease in barometric pressure occurs in a brief period. Although preventive measures are taken, in some instances, altitude decompression sickness (DCS) occurs as a result of these simulations. Although some DCS patients experience resolution of symptoms after receiving ground-level supplemental oxygen, those with persistent or severe symptoms require hyperbaric oxygen (HBO) therapy. Onset of DCS can occur up to 24 hours after altitude exposure, necessitating rapid access to HBO therapy.

The benefit of civilian–military partnerships is increasingly being recognized as the military works to contain costs and Congress has mandated services to decrease their footprints. There is a precedent for partnerships between community hospitals and the military for purposes such as maintenance and development of skills for trauma care providers. This article describes the arrangement between a community hospital in Colorado and a local military base that conducts high-altitude flight simulation for flight crew members in the southwest region. Through this arrangement, cases of DCS are treated locally and rapidly as they occur. The local military base previously operated a hyperbaric chamber, which was closed as a result of concerns about cost. Before the closure, the military base formalized an agreement with a local community hospital to ensure access to treatment. The community hospital operates a HBO chamber for a variety of conditions for which HBO therapy is indicated, such as carbon monoxide poisoning, wound care, and radiation-induced tissue injury.

We estimate the cost per treatment to the institution providing HBO treatment, comparing costs to the community hospital and projections for a standalone center at various patient volumes to examine cost implications of assuring rapid access to appropriate and efficient care.

MATERIALS AND METHODS
Study Design and Participant Selection
The research protocol was approved by UC Health Institutional Review Board and issued documentation of exemption from the Colorado Multiple Institutional Review Board. For the cost data collection, we identified key informants in the finance department with access to financial records. These individuals also reviewed our analyses for accuracy.
Data Collection and Analysis
We conducted a chart review to determine frequencies and demographics of cadets and other military personnel flight crew members or trainees treated for altitude training-related DCS at the community hospital between October 2003 and April 2015.

Cost Data Collection and Estimation
We employed a micro costing framework to measure the direct and indirect costs of delivering HBO therapy. We estimated costs for two types of entities: the community hospital and a standalone chamber, such as those previously operated by the military. We obtained costs from the community hospital’s finance department including: (1) facilities costs, (2) personnel costs, (3) equipment costs, (4) other operating costs, and (5) overhead costs. We also measured number of treatments, as some patients require more than one dive for their condition. To obtain data, we (1) sent a spreadsheet to select key informants with access to financial records and (2) conducted structured follow-up interviews with key informants.

We calculated costs for a single hyperbaric chamber at the community hospital, as well as estimated costs to operate a standalone chamber in order to approximate what it might cost the military to operate their own chamber, as had been done previously. We assumed that personnel, equipment, and other operating costs were similar for the community hospital and a standalone center in the same region.

We used three treatment volumes (5, 100, and 1,000 treatments) for purposes of calculating total and per-treatment costs. The lower end of the range represents the average number of flight crew members requiring HBO therapy each year (5) although the upper end (1,000) more closely reflects treatment volumes at the community hospital, which offers HBO therapy for a variety of conditions.

RESULTS
Characteristics of Study Subjects
Patients Referred to the Community Hospital
Fifty patients with a diagnosis of DCS requiring HBO therapy attributed to military altitude chamber training were referred to the community hospital between October 2003 and April 2015, an average of 4.3 patients annually. Of the 50 patients, 68% were male and 32% were female. Mean age was 21.8 (range 18–40).

Military–Community Hospital Partnership—Need for Access to HBO Therapy
Incidence of DCS requiring HBO therapy was low; however, this emergent capability is a requirement for operations of altitude chambers. To mitigate the potential for DCS, altitude chambers require the participants to breathe 100% oxygen (to offload nitrogen) before the simulated rise in cabin altitude. Additionally, a trial rise in altitude to 5,000 feet above ground level is conducted, in an early attempt to identify participants who might have issues before ascending to a higher altitude, although this does not prevent all untoward effects.

A conservative estimate by the base operating the flight simulation chamber indicated that 0.0026% of individuals undergoing flight simulation required treatment in the hyperbaric chamber over the past 5 years, with an average of 2,306 annual potential exposures including flight crew members, trainees, and instructors. Incidence of DCS is likely to be higher, as some DCS cases are resolved with supplemental oxygen provided at the flight simulation site.

Cost Analysis
Assumptions
This analysis assumes that, on the basis of data from the community hospital, for 100 treatments or fewer annually one chamber is sufficient, whereas volumes of 1,000 or more treatments require three chambers. Hyperbaric chambers are rented from an outside vendor that also provides maintenance and training. This analysis assumes that a standalone center would rent chambers similar to the community hospital.

Fixed, Quasi-Fixed and Variable Costs
Operating expenses for HBO therapy are largely fixed and quasi-fixed (fixed up to a particular threshold of patient volume). Variable costs account for a small proportion of the total operating cost. Variable costs include oxygen and supplies that are dependent on patient volume. Fixed costs include capital costs for equipment other than the chambers that are not sensitive to patient volume. Equipment depreciation costs are also fixed when considering the 5-year depreciation period. The directorship cost is fixed, as is the overhead rate. The community hospital overhead rate includes incremental indirect costs incurred relative to the hyperbaric department. The standalone center overhead rate includes the same components as the community hospital, with the addition of hospital administration costs. Actual overhead costs for a standalone center may be higher, as services such as information technology and financial services are not included in the estimate.

Quasi-fixed costs refer to costs that are fixed up to a particular threshold of patient volume (volume may vary by type of cost). These costs include rent and common area maintenance (CAM) for the standalone center. The community hospital center incurs no rent because the building is owned by the hospital but does incur CAM expenses. Labor and benefits are quasi-fixed, because of the core staffing level necessary to maintain 24-hour operations. After an inflection point, additional labor is needed to maintain higher patient volumes. Purchased services including rental and maintenance of chambers are also fixed for patient volumes under 100 that require one chamber. Increased patient volume requires more chambers.
TABLE I. Estimated Operating Expenses for Hyperbaric Oxygen Therapy Treatment by Patient Volume (5–1,000 patient visits) and Facility (Standalone Center [SC] vs. Community Hospital [CH])

<table>
<thead>
<tr>
<th>Facility Costs</th>
<th>5 Treatments</th>
<th>100 Treatments</th>
<th>1,000 Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SC</td>
<td>CH</td>
<td>SC</td>
</tr>
<tr>
<td>Rent</td>
<td>28,000</td>
<td>0</td>
<td>28,000</td>
</tr>
<tr>
<td>Common Area Maintenance</td>
<td>20,799</td>
<td>20,799</td>
<td>20,799</td>
</tr>
<tr>
<td>Personnel Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor and Benefits Cost</td>
<td>197,769</td>
<td>197,769</td>
<td>197,769</td>
</tr>
<tr>
<td>Equipment Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment Rental Cost</td>
<td>26,000</td>
<td>26,000</td>
<td>26,000</td>
</tr>
<tr>
<td>Capital Costs (Equipment Other Than Chamber)</td>
<td>107,397</td>
<td>107,397</td>
<td>107,397</td>
</tr>
<tr>
<td>Equipment Depreciation Cost</td>
<td>9,370</td>
<td>8,175</td>
<td>9,370</td>
</tr>
<tr>
<td>Other Operating Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Costs Including Oxygen</td>
<td>88</td>
<td>88</td>
<td>1,753</td>
</tr>
<tr>
<td>Purchased Services Including Directorship</td>
<td>38,250</td>
<td>38,250</td>
<td>38,250</td>
</tr>
<tr>
<td>Overhead Rate</td>
<td>49,229</td>
<td>43,903</td>
<td>49,229</td>
</tr>
<tr>
<td>Total Cost</td>
<td>476,902</td>
<td>442,381</td>
<td>478,568</td>
</tr>
<tr>
<td>Cost per Treatment</td>
<td>95,380</td>
<td>88,476</td>
<td>95,380</td>
</tr>
</tbody>
</table>

“The table assumes for 100 treatments or fewer one chamber (1,000 sq ft) is needed, for 1,000 or more treatments, three chambers (3,015 sq ft) are needed.

"Equipment depreciation costs for equipment would cost the same given equal equipment costs. The lower costs for the community hospital reflect the remaining depreciation left on the equipment.

Total and Per-Treatment Costs

Total costs for HBO treatment vary on the basis of patient volume and number of chambers. For five treatments/year, the total cost is estimated at $476,902 for a standalone center, $442,381 at this community hospital, resulting in per-treatment costs of $95,380 and $88,476, respectively. At a volume of 1,000 treatments, total costs are $788,847 for a standalone center and $697,905 at this community hospital, with per-treatment costs of $789 and $698, respectively (Table I).

DISCUSSION

High-altitude flight simulation is a necessary component of training for military flight crew members and trainees. Because altitude exposure carries an inherent risk of DCS, the training site must have an agreement in place to ensure trainees can access HBO therapy if such capacity is not available on site. This article provided an example of a military–community hospital partnership that was described by key informants as beneficial to the military. As such, results from this article suggest that access to HBO therapy needed by the military can successfully be accessed through partnerships with community organizations. These findings may have implications for other rare resources that are needed by the military.

Our results suggest that the per-treatment cost of operating a standalone center with low patient volume is more than 1,000 times the cost than a community hospital with a larger patient volume, from the perspective of the organization providing services. In this case, the finding may be explained by the low incidence of DCS requiring HBO therapy and the high fixed and quasi-fixed costs of operating an HBO chamber. These findings are supported by discussions with seven key members of the community hospital treatment teams, military personnel at the training site and other personnel involved with high-altitude flight simulation and decompression sickness treatment. These experts consulted indicated that the community hospital partnership is beneficial to the military in terms of cost and access to needed care.

LIMITATIONS

This study has several inherent limitations including the fact that the facilities, personnel, equipment, and operating costs of operating a standalone HBO chamber are assumed to be similar to the costs to the community hospital. As such, the cost difference is theoretical and it is unknown whether that cost is the same as it would cost to operate a military chamber. The extent to which these findings are generalizable is unknown.

It is important to note that health care costs at military facilities can be higher than civilian facilities, partially the result of additional readiness requirements for military personnel. This analysis did not adjust for this fact. However, this could further support the finding that the partnership may be economically beneficial to the military.

Additionally, the cost of operating a HBO chamber was examined from the perspective of the organization providing the service. Although focusing on a single perspective
is an inherent feature of economic studies, future research should examine the costs from a variety of perspectives including the total cost to the military of HBO therapy, as well as the reimbursement to the community hospital for HBO therapy services.

CONCLUSION
This study examined the partnership between the military and a community hospital for provision of HBO therapy for DCS. Participants reported that the partnership is beneficial to the military in terms of cost and access to services necessary for training military personnel. Cost analysis results suggest that the current arrangement is substantially less costly than maintaining and operating on-site HBO therapy. Similar partnerships for rare resources such as HBO therapy may be beneficial to the military.

ACKNOWLEDGMENTS
The authors would like to thank David West, PhD, for his guidance, as well as Elizabeth Staton, MSTC, and Kellar Elliott, BS, for their help in preparing and reviewing the manuscript.

REFERENCES