Long-Distance Transport of Ventilated Patients: Advantages and Limitations of Air Medical Repatriation on Commercial Airlines

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Introduction: To illustrate the advantages and limitations of transporting ventilated intensive care unit patients over intercontinental distances on commercial airlines, this case series reports 8 ventilated patients repatriated by an air medical transport company.

Patients: Eight ventilated patients, 3 suffering from internal and 5 from neurologic diseases. Distances ranged from 1700 to 10280 nautical miles with transport times from 04:10 hours to 21:55 hours. For 3 patients, a dedicated patient transport compartment (PTC) in the aircraft cabin was used. All patients were ventilator-dependent for a minimum of 11 days before transport (48 days median, 113 days maximum).

Results: One patient went into cardiac arrest during the flight and died. None of the other patients experienced any emergency or invasive procedures, other than peripheral venous access necessary during the flight. In all patients, ventilation was adjusted with respect to the blood gas analysis at least once during the transport. No technical failures or drop-outs occurred during the flights. None of the flights had to be diverted for technical or medical reasons.

Conclusion: Long distance international transport of ventilated intensive care unit patients is an extremely cost intensive and logistically challenging task. In a certain subgroup of relatively stable ventilated patients, transport on commercial airlines offers advantages in terms of cost effectiveness and reduced transport time and acceleration/deceleration trauma as a result of multiple fuel stops.

Introduction

Travel for business or recreational purposes is increasingly taking people away from their home countries. If those travelers fall ill abroad, repatriation becomes necessary. During the past decades, the travel insurance industry has provided the traveler with cost coverage for treatment abroad and repatriation to the home country.[1] Whereas slight to moderately ill or injured patients commonly are transported seated or on a stretcher on commercial airlines, critical care patients, especially if ventilated, usually require dedicated air ambulance (AA) jets for air medical transport (Figure 1).

These aircraft, however, are extremely costly—up to €5000 Euro ($6100 US dollars) per hour on long-distance intercontinental flights and demand frequent stops for refueling, which represent an additional burden for the patient because of pressure changes and acceleration/deceleration forces.[2] Therefore, the transport of stable and ventilated critical care patients using commercial airlines represents a cost-effective

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and useful alternative to AA on long intercontinental flights (Figure 2).

Patients

The cases of ventilated patients are reported who were transported ventilated on commercial airlines by the air medical transport company Med Call in Wiesbaden, Germany. Patients eligible for transport were not in acute respiratory failure, had an oxygenation index (FIO_2 × Mean Airway Pressure (PAW) / PaO_2 × 100)[3,4] below 10 while the transport was planned, and were not on high-dose inotropic support. The feasibility of transport on a commercial airliner was discussed before all transport among the treating physician, the transport company's medical director, and the medical director of the airline or his representative. Medical clearance was determined by using the standardized MEDIF form and a current medical report from the treating physician.

Transport by commercial airline was possible only if stretcher space was available and the route was served by an airline willing to accept a ventilated patient.

Methods

All patients were accompanied by a physician and nurse. All medical team members had several years of experience in intensive care and air medical medicine and were licensed by the German Medical Association. The transport team arrived in the referring hospital 1 day before transport to examine the patient and test compliance with the transport ventilator.

Equipment

A Mallinckrodt Achieva PS Ventilator (Mallinckrodt, Hazelwood, Missouri, USA) was used for all but 2 transports; those patients were ventilated with a Draeger EV 801 (Draeger Medizintechnik, Luebeck, Germany) or a Breas LTV 1000 (Breas, Mölnlycke, Sweden). A portable blood gas analyzer (Abbott I-STAT Portable Clinical Analyzer, Abbott Laboratories, East Windsor, New Jersey, USA) was used for point-of-care testing during all transports. Patients were monitored with a Siemens Sirecust SC6002 monitor (Siemens-Medical-Solutions, Erlangen, Germany). Medications and fluid were administered using Braun Perfusor Compact syringe pumps (B. Braun, Melsungen, Germany). The medical crew carried electrical and manual suction units and a standardized set of equipment, including a board spectrum of medications, infusions, enterogastric (EG) tube feedings, and nursing supplies, on every transport.

Power supply

Because commercial airlines do not supply power for medical equipment during flight, all equipment was powered by batteries during the transport. The ventilator using maximum 2 A/24 V and the monitor system using maximum 2.5 A/12 V were operated with a power-pack consisting of two 80 (Ah) /12 V gel batteries, delivering 80 Ampere hours (Ah)/24 V or 160 Ah/12 V, allowing more than 24 hours of operation on maximum power demand. The ventilator had a minimum 4-hour back-up internal battery.

Figure 1. Interior of a Learjet 35A air ambulance jet, one of the widely used aircraft in the air medical transport industry. Although this economic aircraft has good range, airspeed, and ICU equipment, the cabin height is only 1.3 m.

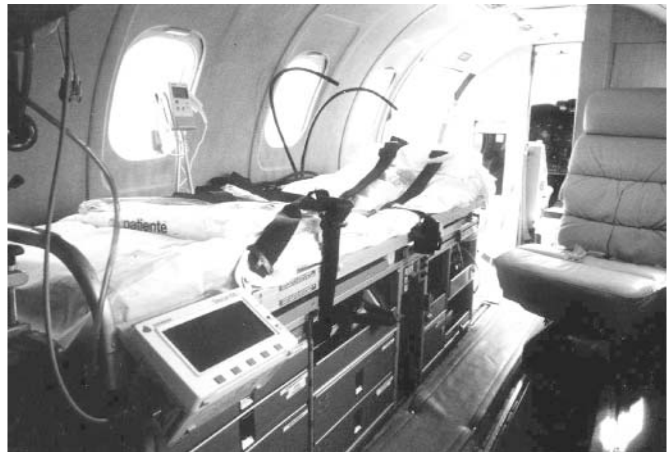

Figure 2. A ventilated (tracheotomy) patient on a stretcher in a Boeing 747-400 on a long haul flight. The stretcher with the ICU equipment occupies 3 rows of seats in economy class and is installed on the left side in the rear of the cabin. The patient and medical personnel are separated by a curtain from the surrounding passengers.

The syringe pumps ran on 4 regular 1.5 V batteries for a minimum of 80 hours.

The electrical suction pump had an internal battery, allowing a minimum of 2 to 3 hours nonstop operation, plus a 12 V charge option.

Oxygen supply

Because high-pressure oxygen tanks are not permitted on any commercial airliner, oxygen was supplied by the airline with a flow of 2, 4, or 6 L per minute, using either aviation-

Table 1

PATIENT CHARACTERISTICS: DIAGNOSIS LEADING TO REPATRIATION AND/OR VENTILATOR DEPENDENCY

Patient	*Age, y*	*Diagnoses*	*Transport Route*	*Ventilation Mode*	*Min FIO_2 During Transport*	*Max FIO_2 During Transport*	*Max OI Prior to Transport*
1	40	Scoliosis, pneumonia	ORD–MAD	SIMV	0.30	0.60	9.5
2	30	Guillian-Barré syndrome	LHR–SYD	SIMV	0.21	0.30	8.3
3	23	Intracranial tumor	SCL–FRA*	SIMV	0.21	1 (during CPR)	2.5
4	67	Intracerebral hemorrhage	FRA–NRT*	CPAP/SIMV	0.40	0.50	2.4
5	54	Unknown primary carcinoma, superior vena cava syndrome, ARDS	MNL–FRA*	SIMV	0.60	0.75	8.3
6	61	Hypoxic brain damage	LHR–DAC	SIMV	0.30	0.40	3.7
7	55	Pneumonia	TFS–LHR	CPAP/PSV	0.40	0.80	CPAP
8	49	Neurodegenerative disease	LHR–DXB	CPAP/PSV	0.30	0.30	CPAP

Airports: LHR, London Heathrow/Great Britain; FRA, Frankfurt Main/Germany; NRT, Tokyo Narita/Japan; TFS, Tenerife South/Spain; ORD, Chicago O'Hare/United States; MNL, Manila/Philippines; DAC, Dhaka/Bangladesh; DXB, Dubai/United Arab Emirates; SCL, Santiago de Chile/Chile; MAD, Madrid/Spain.

ARDS, Acute respiratory distress syndrome; SIMV, synchronized intermittent mandatory ventilation; CPAP, continuous positive airway pressure; PSV, pressure support ventilation; OI: oxygen index ($FIO_2 \times Paw/PaO_2 \times 100$) maximum in the past 7 days before the transport, maximum and minimum FIO_2 during transport
**Patients transported with the Lufthansa patient transport compartment*

approved oxygen tanks from the airlines with fixed flow rates or oxygen concentrators. By combining 2 bottles/concentrators, oxygen flows of up two 12 L per minute were possible. Oxygen flow was introduced into the ventilator tubing close to the patient's endotracheal tube connector or into the air inlet of the ventilator, and FIO_2 rates were calculated using the normogram supplied by the manufacturer.

Results

Eight patients were transported. Patient characteristics, diagnoses, and routes are summarized in Table 1. Almost all patients were repatriated because of acute illness or injury while they were abroad on holiday or as expatriates. One patient (no. 8) was repatriated after being transferred abroad for specialist diagnostics and treatment. One additional patient, suffering from intracranial hemorrhage, was planned to be transferred from South Africa to Great Britain, but the airline withdrew the clearance 1 day before transport, so the patient had to be transported by private AA.

One patient went into cardiac arrest during the flight and died despite sustained cardiopulmonary resuscitation. The event leading to the arrest most probably was brain stem herniation because of the underlying inoperable intracranial tumor, a diagnosis that was well known and discussed before transport. However, in consensus with the patient and relatives, the attempt was made to transport the patient to his home country for palliative care. The flight was continued to the planned destination, were the local government authorities were informed of the death.

No emergency or invasive procedure, other than peripheral venous access, was necessary for any of the other patients during flight. In all patients, ventilation was adjusted with respect to the blood gas analysis at least once during the transport. No medication, other than that planned, was administered.

All patients had been ventilated for more than 11 days before transport (48 days median, 11-113 range). In none of the patients was the oxygen index greater than 9.5 before the transport (6 median, 2.4-9.5 range). No technical failures or drop-outs occurred during the transports. None of the flights was diverted for technical or medical reasons.

Discussion

If a person falls ill abroad and needs critical care treatment, repatriation to the country of origin becomes increasingly difficult. Almost all patients who depend on a ventilator are transported by AA; only 2 reports[5,6] could be found of transports of a ventilated patient on commercial airlines. Although ambulance jets represent a reasonable mode of transport for short and mid-range distances, long-distance transports show some significant drawbacks. Costs increase dramatically on intercontinental routes. One hour of operating a Learjet 35A, one of the smaller and more economical AA jets, is calculated at roughly €2500 ($3055 US dollars), adding up to €45,900 ($56,100 US dollars) for a Chicago-to-Madrid flight. Because this aircraft has a range of 2200 nautical miles, at least 2 stops for refueling are required (in Goose Bay, Newfoundland, and Shannon, Ireland), further contributing to extended transport times and representing an additional risk for the patient in terms of pressure changes and acceleration/deceleration forces. Although those stops can be eliminated or reduced by using aircraft with a greater range, such as a Challenger 604, the cost for 1 hour of operation increases to €5000 ($6100 US dollars). In this context, repatriation of ventilated intensive care unit patients using

Table 2

COMPARISON OF TRANSPORT BY COMMERCIAL AIRLINES AND PRIVATE AIR AMBULANCE†

			Commercial Airline			*Lear 35A*		*Challenger 604*	
Patient	*Transport Route*	*Distance (nm)*	*Transport Time No. of Fuel Stops (h:min)*	*Cost Euro ($US)‡*	*Airline*	*Transport Time No. of Fuel Stops (h:min/n)*	*Cost, Euro ($US)‡*	*Transport Time No. of Fuel Stops (h:min)*	*Transport Cost, Euro ($US)‡*
1	Chicago-Madrid	4500	08:00	4500 (5500)	Iberia	13:05/2	45,900 (56,000)	10:30	93,000 (113,600)
2	London-Sydney	10,280	21:55/1	14,400 (17,600)	Qantas	31:00/6	105,000 (128,200)	26:55/3	204,600 (249,900)
3	Santiago-Frankfurt	7170	16:50	13,900 (17,000) /57,090 § (69,700)§	Lufthansa	20:35/4	74,000 (90,400)	21:05/2	164,800 (201,300)
4	Frankfurt-Tokyo	5600	11:00	16,600 (20,300) /51,470§ (62,900)§	Lufthansa	16:55/3	57,000 (69,600)	14:35/1	115,800 (141,400)
5	Manila-Frankfurt	6050	15:30	13,200 (16,100) /50,820§ (62,100)§	Lufthansa	17:50/3	71,000 (86,700)	15:35/1	126,000 (153,900)
6	London-Dhaka	4690	10:15	13,700 (16,700)	British Airways	13:35/2	57,500 (70,200)	12:40/1	101,000 (123,400)
7	Tenerife-London	1700	04:10	4900 (6000)	British Airways	04:25/0	18,500 (22,600)	04:20	43,000 (52,500)
8	London-Dubai	3200	07:00	6900 (8400)	Emirates	09:00/1	31,700 (38,700)	07:50	66,200 (80,900)

Transport times calculated with fuel stops 45 min for air ambulance (AA) and according to published time tables for commercial airline.
†Cost includes all tickets for patient; stretcher; PTC fees (if applicable) and return trips for the medical team on airlines; and all costs for the flight for the AA. None of the prices include medical crew, medical equipment, or hotel accommodation during stopovers.
‡Based on exchange rate on December 8, 2003.
§ Cost of transport with the Lufthansa patient transport compartment (PTC).

commercial airlines seems to be a considerably attractive alternative (Table 2).

However, AAs present some important logistical and medical advantages compared with commercial airlines. AA transports are much more flexible in terms of routing and time of transport, as well as the use of small airfields near the referring and admitting hospitals to avoid long ground or air transportation to and from international airports. In-flight emergencies of unstable patients might require diversion to the nearest hospital, which is easy to realize with an AA. Whereas the time frame in transports on commercial airlines has to be defined some days before transport to arrange and book the stretcher space, an AA can tailor transport times to the patient's condition, which is especially valuable in critically ill or unstable situations.

The 2 medical conditions that definitely rule out the possibility of transport on a commercial airliner and require AA instead are air leaks requiring transport with sea level cabin pressure or contagious diseases.[7] In addition, the possibility of performing invasive interventions on a commercial airliner is limited by difficult patient access, disturbance of surrounding passengers, and limited space. Combined with the discussed logistical limitations, we believe that critically ill patients with a high oxygenation index or inotropic support and patients with fever of unknown origin or short intensive care unit stays and unclear diagnosis should not be repatriated by commercial airlines.

After identifying patients eligible for this kind of transport, close attention should be paid to team composition and equipment. All our transport teams consist of a physician and a nurse according to the German legal requirements for interhospital transport of critically ill patients, although the value of the physician in transport teams is, especially in the United States, a point of controversy.[8] Obviously, the team must have outstanding experience in air medical transports using AA before transporting patients in the less flexible and longer commercial airline environment. Because technical failure of life-sustaining technology is a critical issue in air medical transport, regular checks of equipment and power supplies and detailed knowledge by the medical team concerning technical pitfalls and basic troubleshooting procedures are essential. This necessity is highlighted by the fact that extended transport times make the occurrence of equipment-related adverse events even more likely.[9] In addition to the standard critical equipment, a portable blood gas analyzer is of major importance to monitor proper ventilation of patients during these extremely long transport times.[10]

In 3 patients in the current study, a dedicated patient transport compartment (PTC) in the cabin of the airliner was used. In this galley-like compartment developed by Lufthansa, the patient is transported on a stretcher, and a power supply and drawers for the medical and technical equipment are provided. Because the aircraft hosting the PTC (B 747-400 and A 340) is equipped with an excess pressure relief valve through the hull, Lufthansa provides high-pressure oxygen and a 220/110 V power supply to the PTC, allowing an easier in-flight operation of medical equipment. In addition, the compartment separates the patient from other passengers, providing considerably more privacy than a stretcher, although there is no separate air conditioning.

However, these advantages are limited by restricted availability and significantly increased costs compared with stretcher transports (Table 2). Since only Lufthansa routes served by B 747-400 and A 340 aircraft can be flown with the PTC, air ambulance transport from and to Lufthansa hubs may further increase the cost.

Conclusion

Long-distance international transport of ventilated critically ill patients is an extremely cost-intensive and logistically challenging task. In a certain subgroup of relatively stable long-term ventilated patients, transport on commercial airlines offers advantages in terms of cost-effectiveness and reduced transport times and acceleration/deceleration trauma from multiple fuel stops.

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