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Deterioration of respiratory function after intra-hospital transport of critically ill surgical patients

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Abstract *Objective:* To evaluate the impact of intra-hospital transport of artificially ventilated patients on respiratory function, and to define predictors that may allow estimation of the risk of post-transport pulmonary deterioration.
Design: Prospective observation study.
Setting: Surgical ICU, University Hospital.
Patients: 49 intra-hospital transports (median Apache-score before transport 21, of 28 consecutive patients (all intubated and mechanically ventilated) were studied.
Interventions: 32 transports were destined to the radiology department and 17 to the operating theatre. Patients were ventilated during transportation with a transport ventilator.
Measurements and results: The base-line condition of the patients and any changes of hemodynamic function were noted. Arterial blood gases were determined before transport as well as 0.25, 1, 6, 12, and 24 h after return of the patient to the ICU. Of the transports 41 (83.7%) resulted in a decrease of PO_2/FIO_2-ratio with a deterioration of more than 20% from baseline in 21 cases (42.8%). The impairment of respiratory function lasted longer than 24 h in 10 subjects (20.4%). Ventilation with positive end-expiratory pressure correlated significantly ($r = -0.4$) with post-transport change of PO_2/FIO_2-ratio, whereas initial FIO_2, initial PO_2/FIO_2-ratio, Apache II-score, patients' age or transport time did not distinguish between patients with and without a consecutive decrease of pulmonary function.
Conclusion: Intra-hospital transport of ventilated critically ill patients may result in a considerable and long-standing deterioration of respiratory function. Patients ventilated with positive end-expiratory pressure are at an increased risk and the indication for procedures away from the ICU has to be weighed carefully in these subjects.

Key words Pulmonary function · Mechanical ventilation · Ventilators · Transportation of patients · Intra-hospital transport

Introduction

Critically ill surgical patients may be subject to an increased rate of intra-hospital transport for diagnostic or therapeutic procedures that cannot be performed at the bedside but require transfer of an individual to another department within hospital. Such procedures comprise abdominal computed tomography to detect necrotizing pancreatitis [1] or intra-abdominal abscess [2, 3], thoracic computed tomography to rule out intra-pulmonary abscess or empyema [4], cranial computed tomography for

follow-up of intracranial trauma [5], angiography for the detection of thromboembolic complications [6] and others. CT-guided puncture [7] necessitates transport of the patient to the radiology department. Furthermore, therapeutic interventions such as tracheotomy [8], ventriculotomy [9] or scheduled reoperations for peritonitis with open abdomen [10] may be performed either at the bedside in the intensive care unit (ICU) or in the operating theatre. The indication for transferring critically ill patients within hospital has to account for the stability of the patient's condition, the undesired impact of disconnecting him from his location in the ICU, and the potential benefit from the intended procedure. Although the immediate complications of respiratory and hemodynamic function during intra-hospital transport have been documented [11–14] no conclusive data are available on the long-term effects of such transports. In order to decide if and which critically ill patient might be harmed by a transport within hospital, we studied pulmonary function of artificially ventilated patients from a surgical ICU before intra-hospital transport and after their return to the ICU.

Materials and methods

Patients

A total of 49 intra-hospital transports of 28 consecutive patients were studied prospectively. All patients were intubated and mechanically ventilated. There were 21 male and 7 female individuals with a median age of 38 years (range 18–79). There were 36 transports involving patients with multiple injuries or major trauma to the head and 13 transports comprised subjects with intra-abdominal pathology (peritonitis, pancreatitis). The median Apache II-score before the 49 transports was 21 points with a range from 7–35. There were 32 transports destined to the radiology department (28 had computed tomography, 4 had angiography) and 17 to the operating theatre (7 abdominal revisions, 6 fracture stabilisations, 2 ventriculotomies, 1 tracheotomy, 1 abscess drainage).

Transports

The patients were transferred to their destination in their patient bed. They were connected to a portable ECG-monitor and a pulseoximeter. All essential medication was continued with battery operated perfusor pumps with no interruption occurring. As the last step of disconnecting the patients from the equipment on the ICU they were put on the transport ventilator immediately before the transport. In a total of 36 cases the patients were sedated during transport with sedation continued on the pre-transport level, increased above pre-transport level or given only during transport in 25, 8 and 3 cases, respectively. Muscle relaxants were administered in 2 patients. During transportation, ventilation was maintained by means of a time cycled, volume constant portable ventilator (Oxylog Emergency Ventilator: Drägerwerke AG, Lübeck, FRG). It has the same flow pattern (rectangular) as was used with the ventilators in the ICU. The I:E ratio of the Oxylog is fixed to 1:1.5 and thus was varied from the pre- and post-transport setting in some patients. Respiratory rate and tidal volume during transport were set to the same adjustments as were used in the ICU. Patients with a pre-transport fraction of inspired oxygen (FIO_2) equal or below 0.4 were ventilated with the 'air mix' position ($FIO_2 = 0.5$), the remainder with the position 'no air mix' ($FIO_2 = 1.0$). Positive end-expiratory pressure, if used, was maintained on the pre-transport level with the use of a valve at the exhalation port (PEEP valve (Ambu): Drägerwerke AG, Lübeck, FRG). The correct adjustment of the valve was controlled by the reading at the airway pressure gauge. After arriving at their destination the patients were placed on the examination stretcher or the operating table. Ventilation was continued with the settings used in the ICU with either a Siemens Servo C ventilator (radiology department, same type of ventilator as in the ICU) or comparable ventilators from different manufacturers (operating theatre). During surgery volatile anaesthetic agents were used most of the time. The continuation of intensive care in the operating theatre was performed by anaesthetists. After completion of the diagnostic or therapeutic procedure the patients were immediately returned to the ICU.

The PO_2 was kept in a constant range during the whole observation period by increasing either the FIO_2 ($n = 20$), the level of PEEP ($n = 2$) or both ($n = 10$).

The median transport time to reach the destination was 13 min (range 5–30 min) and the total duration of absence from the ICU for diagnostic procedures and for surgery was 73 min (35–200 min) and 150 min (69–345 min), respectively. The operating theatre is located on the same floor opposite the ICU and the radiology department is one floor down. The distance from the stationary position of the beds in the ICU to the entrance of the ICU varied between 35 and 45 m.

Measurements

Before transport Apache II-score, type and dosage of administered drugs as well as type, volumes and pressures of ventilation were recorded. Blood pressure and heart rate were determined at the time of blood gas analysis (see below); an increase in catecholamine dosage was considered a major hemodynamic instability. Arterial blood gases were determined (AVL 995 Automatic blood gas system: Graz, Austria) in the steady state immediately before the disconnection for transport was begun. The time to reach the destination and until return to the ICU was noted. The next blood gas analysis was done 15 min after the patient had returned to the ICU and had achieved a steady state. Further measurements were performed 1, 2, 6, 12 and 24 h later.

Statistics

To discriminate between moderate ($\leq 20\%$) and major ($> 20\%$) decrease in PO_2/FIO_2-ratio the first PO_2/FIO_2-ratio (15 min after transport) was chosen. For statistic analysis the Wilcoxon-Mann-Whitney-U-Test or the χ^2-test was used for inter-group comparison and the Wilcoxon signed rank test to check for intra-group differences. Correlation analysis was done with non-parametric rank correlation (Spearman). The study was performed in accordance with the guidelines of the Ethical Committee of the University of Munich and the principles established in Helsinki.

Results

The time course of PO_2, FIO_2, level of PEEP and PO_2/FIO_2-ratio before and after intra-hospital transport

Table 1 Level of PO_2, FIO_2, PEEP and PO_2/FIO_2-ratio before (baseline) and after intra-hospital transport ($n = 49$). The data are given as median (with quartiles)

*$p < 0.05$ compared to baseline level before transport, Wilcoxon signed rank test

	PO_2 (mmHg)	FIO_2	PEEP (mmHg)	PO_2/FIO_2-ratio
Baseline	85 (76 – 90)	0.3 (0.28 – 0.4)	4 (0 – 5)	267 (198 – 303)
posttransport				
15 min	80 (71 – 99)	0.4 (0.3 – 0.5)*	4 (0 – 6)	220 (175 – 270)*
1 h	91 (76 – 140)*	0.4 (0.4 – 0.5)*	4 (0 – 6)	220 (170 – 320)*
2 h	86 (78 – 102)	0.4 (0.3 – 0.5)*	4 (0 – 6)	252 (183 – 317)
6 h	83 (74 – 90)	0.35 (0.3 – 0.45)	4 (0 – 6)	247 (200 – 293)*
12 h	80 (73 – 92)	0.4 (0.28 – 0.4)	4 (0 – 6)	246 (200 – 307)*
24 h	79 (73 – 88)	0.3 (0.28 – 0.4)	4 (0 – 6)	250 (183 – 316)*

are shown in Table 1. The PO_2/FIO_2-ratio was significantly decreased immediately after the transport and remained at a lower level during the first 24 h. To keep the PO_2 level constant the FIO_2 had to be significantly increased (in 30 of 49 patients), whereas the level of PEEP had to be elevated in 12 of 49 patients.

There were 41 (83.7%) of transports resulting in a deterioration of respiratory function as defined by a decrease of the PO_2/FIO_2-ratio. The PO_2/FIO_2-ratio worsened by more than 20% (from its initial value before transport) after 21 transports (42.8%). The duration of the impairment of respiratory function is shown in Fig. 1. While PO_2/FIO_2-ratio remained unchanged in 8 patients (16.3%) or returned to baseline values within 1 h after return to the ICU in 26.5% ($n = 13$), 10 patients (20.4%) presented with a longstanding impairment of more than 24 h duration. There was a tendency for a longer lasting post-transport respiratory depression in patients with a more pronounced deterioration. In patients with longstanding (>6 h) disturbances of gas exchange ($n = 16$) 11 subjects showed a trend towards their baseline level, 2 remained stable at a reduced level and in 3 patients PO_2/FIO_2-ratio further decreased over the 24-h period.

The patients' baseline data before transport with respect to post-transport pulmonary function are outlined in Table 2. Subjects with a considerable deterioration (>20% from baseline) tended to have sustained surgery more often than those without relevant respiratory impairment but this was not significant. The only significant difference was found for ventilation with positive end-expiratory pressure. The data for the change in PO_2/FIO_2-ratio in relation to positive end-expiratory pressure is shown in Fig. 2. Ten of 17 patients (59%) that required surgery and 17 of 32 subjects (53%) that went to the radiology department required ventilation with positive end-expiratory pressure showing no significant difference between these two groups.

Furthermore, positive end-expiratory pressure correlated significantly ($r = -0.4$, $p < 0.01$) with the post-transport change of PO_2/FIO_2-ratio. No such relationship with a deterioration of PO_2/FIO_2-ratio could be verified for initial PO_2/FIO_2-ratio ($r = 0.05$) (Fig. 3), ini-

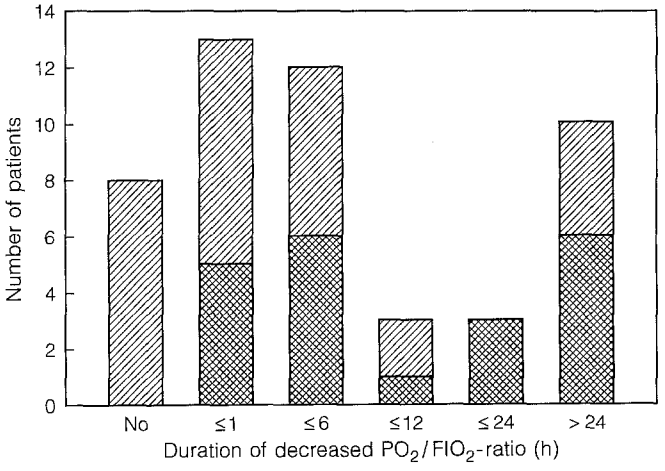

Fig. 1 Duration of decreased PO_2/FIO_2-ratio after 49 intra-hospital transports of ventilated patients. A reduction of PO_2/FIO_2-ratio ≤20% was observed in 28 patients (*diagonal pattern*) and >20% in 21 cases (*crosshatched pattern*)

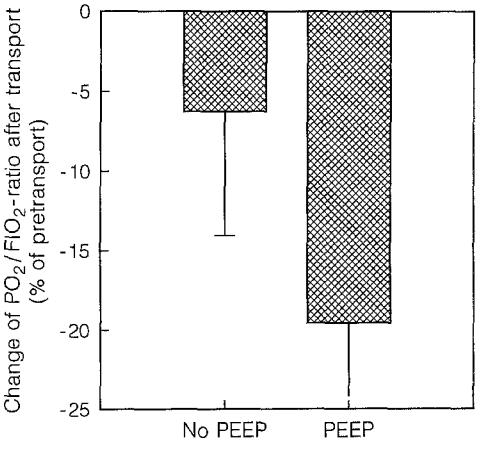

Fig. 2 Change of PO_2/FIO_2-ratio after transport compared to pretransport level in patients with ($n = 28$) and without ($n = 21$) positive end-expiratory pressure (PEEP). The difference is significant ($p < 0.05$, Wilcoxon-Mann-Whitney-U-test)

Table 2 Clinical condition before transport of 28 patients whose respiratory function remained essentially unchanged compared to 21 subjects whose PO_2/FIO_2-ratio decreased by more than 20%. Values are given as median (range in parenthesis) or % of patients

	Decrease of PO_2/FIO_2-ratio		
	>20%	≤20%	
Initial PO_2/FIO_2-ratio	257 (127/446)	272 (97/519)	n.s.
Initial FIO_2	0.3 (0.21/0.7)	0.3 (0.21/0.7)	n.s.
Age (years)	40 (21/63)	42 (18/79)	n.s.
Apache II-score	21.5 (7/35)	20 (13/34)	n.s.
Transport time (min)	15 (10/30)	12 (5/30)	n.s.
Total absence from ICU (min)	80 (35/259)	75 (23/345)	n.s.
Catecholamines	45%	41%	n.s.
Transport to radiology dpt.	60%	69%	n.s.
Transport to operating theatre	40%	31%	n.s.
Plateau airway pressure (cmH_2O)	28.5 (20/29)	24 (18/28)	n.s.
Ventilation with PEEP	80%	41%	$p<0.05$

tial FIO_2 ($r=-0.13$), patient's age ($r=-0.007$), Apache II-Score ($r=-0.05$), transport time ($r=-0.16$) or duration of absence from the ICU ($r=-0.14$).

Minor alterations occurred in catecholamine therapy. Only after 2 transports (4.1%) did patients require an increased amount of catecholamines as compared to baseline. After return to the ICU, 10 patients (20.4%) were noted to have hypocarbia (a fall in PCO_2 of more than 5 mmHg (0.67 kPa)) with concomitant respiratory alkalosis (a rise in pH of more than 0.05) compared to baseline. This condition was reversible within 1 h in all patients.

Discussion

This study indicates that intra-hospital transport of critically ill surgical patients that are artificially ventilated may result in a considerable and longstanding deterioration of pulmonary function in a subset of patients with PEEP ventilation.

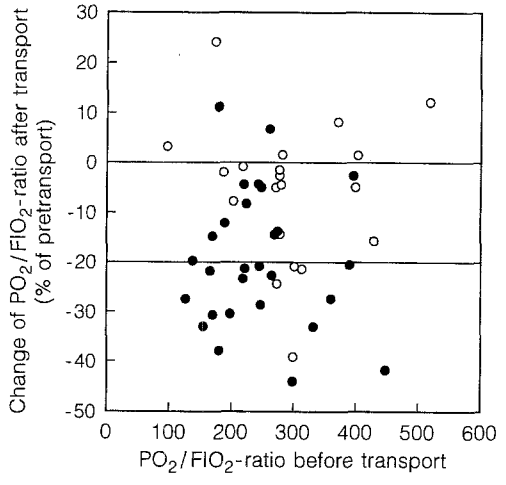

Fig. 3 Individual data for the change of PO_2/FIO_2-ratio after transport in relation to initial PO_2/FIO_2-ratio (pretransport level) for patients with positive end-expiratory pressure (*closed circles*) and those with zero end-expiratory pressure (*open circles*)

It has been reported that post-operative patients that recover from inhalational anaesthesia have an increased risk of significant alterations in hemodynamic function [11] and that high-risk cardiac patients might present with arrhythmias that necessitate emergency therapy in up to 44% of intra-hospital transports [15]. In contrast, no such complications were noted during transport of patients from an ICU, which was attributed to the adequate preparation before transport [11]. These results were confirmed by our findings that a hemodynamic deterioration of such patients is a rare event. Only 4% of our patients needed higher catecholamine doses to maintain cardiocirculatory stability although 35% have been subject to surgical intervention and 84% have been away from the ICU for more than 1 h.

Furthermore, a deterioration of blood gases during transfer of patients from the operating room to the recovery area [16, 17] as well as during transport of critically ill patients has been repeatedly observed [12–14]. These investigators reported a significant respiratory alkalosis due to hyperventilation with manual ventilation of the patients, while oxygenation remained stable. This undesired effect could be avoided by using a respirometer [12] or a transport ventilator [13, 14]. Based on these experiences several mobile transport units for intra-hospital transfer have been recommended [13, 15, 18–20]. We used a system of continuous ECG-monitoring, pulse-oximetry, perfusor pumps and a transport ventilator. The change from one ventilator to another took only a few seconds (without an interval of manual ventilation). With this regimen no immediate complications during transport were encountered. Despite the use of a transport ventilator, changes in pH and PCO_2 were noted in 20.4% of the patients at the return to the ICU. It cannot be ruled out that respiratory alkalosis may have been present even more frequently at some time during the absence from the ICU. These alterations have all been reversible within 1 h.

Our main finding is that about 43% of the patients sustained a considerable deterioration of oxygenation af-

ter they had returned from transport. Although this disturbance was usually transient it took between 6 and 24 h for the PO_2/FIO_2-ratio to return to baseline in 6 patients. 20% ($n = 10$) of the patients, however, did not recover within 24 h.

The only discriminating factor before transport between those subjects, whose respiratory function deteriorated considerably and those who remained more or less stable was ventilation with positive end-expiratory pressure. Since it is known that interruption of positive end-expiratory pressure may result in an immediate decrease in arterial oxygenation that requires a higher level of positive end-expiratory pressure to compensate for [21], part of the deterioration in respiratory function may be attributed to this phenomenon when connections were changed from the stationary unit to the transport ventilator. On the other hand, positive end-expiratory pressure can be interrupted in these patients for tracheal suctioning without such pronounced long-term effects. It cannot be ruled out that the actual positive end-expiratory pressure has been overestimated by the reading on the pressure gauge of the Oxylog. However, the manufactorer of the PEEP valve claims a high precision of the valve and the conformity of the level of positive end-expiratory pressure on the valve's scale and the reading on the pressure gauge suggest a correct level of positive end-expiratory pressure. Furthermore, the use of volatile anaesthetic agents and the reduced reliability of some pressure gauges of ventilators in the operating theatre might have added to an unrecognised change in the level of PEEP in a subset of patients. Neither a high FIO_2 or a high Apache II-score nor the requirement for catecholamines could be identified as risk factor. These observations hold true for patients with a baseline PO_2/FIO_2-ratio as low as 97 and a FIO_2 of up to 0.7. Subjects with worse pulmonary function were not considered for transport during the observation period. Nevertheless the overall condition of the patients studied was critical with a median Apache II-score of 21 points, which indicated a mortality risk of about 40% [22].

It is noteworthy, that the duration of the transport or of the absence from the ICU seemed not to affect the post-transport respiratory performance. Rather than transport distance, the manipulations of changing connections, ventilators and/or stretchers may be of major influence on pulmonary function. Furthermore, a lack of suctioning and turning of the patients during their absence from the ICU might contribute to our observations. Whether radiological interventions such as CT scan or angiography per se will lead to a pulmonary impairment is not known but seems unlikely in view of the small effects that minor operative interventions (e.g. herniotomy) have on body homoeostasis and gas exchange. Interestingly, we observed no significant differences in post-transport respiratory function in patients that underwent therapeutic (surgery) as compared to diagnostic (radiology) interventions. In the subset of 16 patients with longstanding (>6 h) deterioration 38% of the transports were destined for the operating room. The patients of this group did not undergo surgery more often than the subjects with a short living or no fall in PO_2/FIO_2-ratio (transport to the operating room in 33% of the cases) indicating that other factors than the surgical trauma may play an important role in causing increased pulmonary shunting after transport.

The decrease of PO_2/FIO_2-ratio might be attributed to a worsening of the underlying disease and/or pulmonary function even before transport. However, the high coincidence of respiratory deterioration immediately after the transport with a consecutive recovery to or towards baseline levels in most of the patients suggests the significance of mechanisms related to the transport and/or events during the absence from the ICU, respectively.

From our data it cannot be decided, if there is any single most important factor that is actually responsible for the deterioration of pulmonary function. We feel, that the changes observed seem to be rather ascribed to the summarized effect of the variables discussed. It is concluded that intra-hospital transport is comparatively safe for patients that are ventilated without positive end-expiratory pressure and that deteriorations of gas exchange are usually transient. Thus the indication for surgery in the operating theatre or for diagnostics that are performed away from the ICU can be made more easily. On the other hand, in patients treated with positive end-expiratory pressure the benefits and adverse effects of intra-hospital transport need to be weighed more carefully. Bedside surgery and alternative diagnostic procedures may be favoured under these conditions. If such patients are transported within hospital one possibility to reduce adverse effects on gas exchange might be the use of a ventilator that allows the same pattern of ventilation as is applied in the ICU. This is usually not possible with the available transport ventilators. We suggest, like others [18], to use fully equipped mobile ventilator units. Preferably the same type of ventilator as on the ICU, hooked to a mobile power supply, should be used. In the future, more attention has to be devoted to optimising ventilatory support during the critical time of transports of ventilated intensive care patients within hospital.

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