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ORIGINAL ARTICLE

Prevention of complications in the air transport of the critically ill paediatric patient between hospitals☆

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KEYWORDS
Complications during transport;
Helicopter transportation;
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Abstract
Objectives: To analyse the rate of complications recorded during patient transport after applying a stabilisation protocol in the sending hospital, defined by a paediatric critical patients air transport unit.
Materials and methods: We retrospectively analysed the transfers made by the air unit of our hospital over a 5 years period. Patients with respiratory failure, haemodynamic compromise, or neurological involvement were identified. The stabilisation protocol prior to transport is described. Operations performed during stabilisation period, as well as during the transfer are quantified. Complications during transport are recorded and classified into major and minor ones.
Results: A total of 388 patients were transferred, of which 207 had respiratory failure, 124 neurological disorders, and 102 with haemodynamic instability. During the stabilisation period, 295 patients required oxygen and 161 mechanical ventilation. A total of 14 pleural drains, 397 peripheral lines and 97 central lines were placed. Vasoactive drugs were administered on 92 occasions and anticonvulsants in 41. We have performed 24 cardiopulmonary resuscitations, and 2 patients died before the move, and one required surgery.

Twenty major complications have been recorded during transfer (6 neurological, 13 haemodynamic, and 1 respiratory), and 69 minor complications (14 neurological, 29 haemodynamic and 26 respiratory). One patient died.
Conclusion: Compliance with defined stabilisation standards led to a high rate of interventions during the preparation phase. On the other hand, a small number of complications occurred during transport: only 5.1% of the patients showed any serious complication. This low rate of complications is attributable to a correct stabilisation carried out prior to transfer, and based on the standards adopted by the team.

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[1] The members of the Transport team are listed in Appendix A.

PALABRAS CLAVE
Complicaciones durante el transporte;
Transporte en helicóptero;
Transporte pediátrico

Prevención de complicaciones en el transporte interhospitalario aéreo del paciente crítico pediátrico

Resumen

Objetivos: Analizar la tasa de complicaciones registradas durante el transporte después de aplicar los estándares de estabilización en el hospital emisor definidos por una unidad de transporte aérea de pacientes críticos.

Material y métodos: Se analizan retrospectivamente los traslados efectuados por la unidad de nuestro hospital durante 5 años. Se clasifican en pacientes con insuficiencia respiratoria, con compromiso hemodinámico o con afectación neurológica. Se describen los estándares de estabilización y se cuantifican las intervenciones practicadas durante esta fase en el hospital y durante el traslado. Se definen y agrupan las complicaciones entre mayores y menores, y se cuantifican.

Resultados: Se trasladó a 388 pacientes. En el hospital emisor, 207 presentaron insuficiencia respiratoria, 124 trastornos neurológicos y 102 inestabilidad hemodinámica. Durante la estabilización, 295 pacientes precisaron oxígeno y 161 ventilación mecánica. Se colocaron 14 drenajes pleurales, 397 vías periféricas y 97 centrales. Se administraron vasoactivos en 92 ocasiones y anticomiciales en 41. Se practicaron 24 reanimación cardiopulmonar. Dos pacientes fallecieron antes del traslado, uno precisó cirugía.

Durante el traslado, se registraron 20 complicaciones mayores (6 neurológicas, 13 hemodinámicas y 1 respiratoria) y 69 complicaciones menores (14 neurológicas, 29 hemodinámicas y 26 respiratorias). Un paciente falleció durante el transporte.

Conclusión: El cumplimiento de los estándares de estabilización definidos comportó un elevado intervencionismo durante la fase de preparación. En contrapartida, se registró un escaso número de complicaciones durante el transporte. El 5,1% de los pacientes presentó alguna complicación grave. Atribuimos esta baja tasa de complicaciones a la correcta estabilización realizada sobre la base de los estándares adoptados por el equipo.

Introduction

A large number of publications have demonstrated a direct relationship between the volume of admissions and the survival of patients in various highly specialised services.[1] Centralisation of paediatric intensive care units has also been shown to improve results and optimise the cost–benefit ratio of hospitalising critically ill patients.[2] Consequently, tertiary hospitals are centralised in major cities and seriously ill children admitted to local hospitals have to be transferred, making it necessary to establish specialist transport teams.[3]

This entails a risk in addition to that of the patient's actual illness. In 1975 Waddell described a rate of complications as high as 20% during transfer and a resulting increase in mortality; children who required transport were at double the risk of dying compared with those admitted to the Intensive Care Unit from the same hospital.[4] The American Academy of Pediatrics published its guidelines for air and ground transportation of paediatric patients in 1986, with the goal of standardising the transport of critically ill children.[5] In 1990, it founded the Section on Transport Medicine, comprising experts in neonatology, intensive care and emergency medicine working in this area. Since then it has coordinated research and teaching on paediatric transport in the United States. The guidelines were revised in 1993 and 1997.[6,7] All of them agree that the quality of interhospital paediatric transport is determined by two factors: the level of training and specialisation of teams, and optimum stabilisation of patients before transfer.[8]

The aim of this review is to analyse the rate of complications recorded during the transport of critically ill patients after applying the stabilisation standards in the sending hospital, as established by our air transport unit. For this purpose we defined the criteria for stabilisation prior to transport, the interventions resulting from them, the complications arising during transfer and the therapeutic procedures required to resolve them.

Materials and methods

This is a retrospective, descriptive study, which includes patients aged between 0 and 14 transferred by our air unit between January 2005 and December 2009 (5 years). The care team is made up of paediatricians and nurses who carry out air transport exclusively by helicopter.[9] Three diagnostic groups were identified: patients with respiratory failure, patients with haemodynamic instability and patients with neurological involvement.

The stabilisation standards were those described in Table 1.

We recorded the actions performed by staff of the sending hospital and those of the transfer team at the sending

Table 1 Stabilisation standards.

Airway
Isolation of airway in cases of Glasgow score <10 or agitation, structural damage to the face or neck or stridor, or if deep sedation or analgesia is required
Oxygenation
Systematic administration of oxygen to maintain oxygen saturation between 98% and 100%
Ventilation
Manual ventilation if:
FiO_2 requirement >40% to maintain 95% oxygen saturation
pCO_2 > 45 mm Hg
Presence of very laboured breathing with poor response to bronchodilators
Significant restrictive pattern in chest X-ray
Set the mean airway pressure as low as possible to optimise blood gas values
Non-invasive ventilation in cases of moderate distress, with good blood gas values and tolerance. If the slightest doubt arises, one must switch to invasive ventilation
Placement of a chest tube in pneumothorax whether or not under tension
Circulation
Placement of at least two IV lines
Containment of external bleeding
Prior surgical stabilisation of internal bleeding
Maximum stabilisation with volume and/or vasoactive drugs
Optimisation of haemoglobin figures >10 mg/dl
Correction of coagulopathy
Intubation of all haemodynamically unstable patients
Neurological
In the event of craneoencephalic trauma, keep pCO_2 between 35 and 40 mm Hg and SatO2 100%, hyperventilation or hypertonic saline solutions for preventive purposes counterindicated, maintenance of arterial blood pressure at normal levels
Treatment with anticonvulsants for patients who have had convulsions
Avoid curarisation as far as possible
Sedation, analgesia and curarisation
Sedation with midazolam and analgesia with fentanyl
Curarisation in cases of patient-ventilator dyssynchrony

institution, dividing them into oxygen therapy, intubation, connection to invasive or non-invasive mechanical ventilation, pleural drainage, placement of peripheral or central lines, infusion of vasoactive drugs, administration of anticonvulsants and cardiopulmonary resuscitation procedures.

We recorded the complications that arose during transfer, dividing them into major and minor complications and classifying them as respiratory, haemodynamic or neurological. The following were defined as major complications: desaturation lasting more than a minute that was not corrected by increasing FiO_2 or adjusting the ventilator, disconnection of catheters or chest tubes, accidental extubation, drop in arterial blood pressure requiring the administration of at least 10 mL/kg of fluids, arrythmias o cardiac arrest, and clinical signs of intracranial hypertension. Minor complications were desaturation corrected by increasing FiO_2 or adjusting the ventilator, patient-ventilatory dyssynchrony, kinking of the endotracheal tube, drop in arterial blood pressure corrected by modifying the infusion of vasoactive drugs, and convulsions controlled by anticonvulsants.

Table 2 Stabilisation procedures carried out by the professionals at the sending hospital.

Stabilisation procedures sending hospital	Number
Supplementary administration of oxygen	144
Intubation and connection to invasive mechanical ventilation	112
Non-invasive ventilation	4
Placement of chest tube	4
Placement of peripheral lines	317
Placement of central lines	80
Infusion of vasoactive drugs	49
Administration of anticonvulsants	30
Cardiopulmonary resuscitation procedures	20

Results

A total of 388 patients were transferred, 157 male and 231 female. Of these, 167 were neonates and the rest were children of up to 14 with an average age $\pm$ standard deviation of 37 $\pm$ 42 months.

Within the various diagnostic categories, the most prevalent item was acute respiratory failure (207/388), followed by neurological involvement (124/388) and (102/388) patients with haemodynamic alterations.

Tables 2 and 3 describe the stabilisation procedures performed by professionals in the sending hospital and by the transport team prior to transfer, respectively.

A patient with craneoencephalic trauma and a ruptured liver had to be operated on beforehand at the indication of

Table 3 Stabilisation procedures carried out by the transport team.

Stabilisation procedures transport team	Number
Supplementary administration of oxygen	51
Intubation and connection to invasive mechanical ventilation	36
Non-invasive ventilation	9
Placement of chest tube	10
Placement of peripheral lines	80
Placement of central lines	17
Infusion of vasoactive drugs	43
Administration of anticonvulsants	11
Cardiopulmonary resuscitation procedures	4

the transport team on the grounds of haemodynamic instability. Two patients died in the sending hospital.

During the transfer of the 388 patients, 20 major complications (5.1%) and 69 minor ones (17.7%) were recorded. Of these, 27 were respiratory, 42 haemodynamic and 20 neurological. We analysed each group separately and found the following:

Of the total of 27 respiratory complications, 26 were minor: 24 cases of hypoxia, resolved by adjusting the ventilator, and 2 of kinking of the endotracheal tube (ETT) that required repositioning the tube. The major complication was a pneumothorax, for which a chest tube needed to be placed. All the respiratory complications occurred in intubated patients; none of the non-intubated patients had to be intubated during transport and none required adjustment of the oxygen concentration administered.

Of the haemodynamic complications, 13 of the 42 were major: 11 cases of hypotension requiring treatment with fluids, one of cardiac arrest, and one of ventricular fibrillation requiring CPR prior to an emergency landing. The patient with cardiac arrest died. The remaining 29 complications were minor and involved hypotension resolved by adjusting the dose of vasoactive drugs that the patients were receiving. In no case was it necessary to place an intravenous line or initiate continuous infusion of vasoactive drugs during transport.

As for neurological complications, 6 of the total of 20 were major, due to the appearance of clinical signs of intracranial hypertension (IH) which required infusion of hypertonic saline solutions and/or short-term hyperventilation. All the patients with IH had previously been intubated and ventilated. The 14 minor cases involved convulsions which were treated successfully with anticonvulsants.

Discussion

The efficiency of paediatric transport rests on three fundamental principles: specialisation of teams, appropriate stabilisation prior to transport and prevention of complications.

Specialisation of teams

Paediatric transport requires a high degree of specialisation. Macnab in 1991, and Edge et al. in 1994, each published papers showing that the transfer of critically ill children with paediatric teams reduced morbidity compared with non-paediatric teams.[10,11] Another study by Macnab et al. in 2001 demonstrated that specialised teams achieved a better cost–benefit ratio, leading to lower hospitalisation costs, because fewer complications occurred during transfer.[12] Our hospital's paediatric transport unit, with 15 years' experience, undertakes interhospital transfer of patients throughout Catalonia and is part of the Sistema de Emergencias Médicas (Medical Emergencies System).[13] The care staff comprises doctors specialising in paediatrics, paediatricians and holders of university degrees in nursing, with expertise in paediatric and neonatal intensive care. All of them have taken courses in advanced paediatric cardiopulmonary resuscitation, neonatal cardiopulmonary resuscitation, advanced paediatric trauma life support, the course for health care crew in Helicopter Emergency Medical Services (HEMS), and an annual Crew Resource Management (CRM) refresher course. The pilots and co-pilots, for their part, have extensive experience in HEMS and training in advanced life support techniques.

Stabilisation standards

In 2010 Fanara et al. published a review of 66 bibliographical items on adverse events during transport of critically ill adult patients. They emphasised stabilisation prior to transport as a decisive factor in preventing them and distinguished between major and minor complications, categorising them as respiratory, cardiocirculatory or neurological.[14]

They defined major complications as those that required urgent action and put the patient's life at risk. In the case of children, and especially in helicopter transport, the level of stabilisation at the sending hospital must be optimal. Whether complications arise or not during transfer largely depends on this. One must bear in mind that if they do arise, they are extremely difficult to treat on board a helicopter in flight. We must therefore be very careful during this phase of transfer. The stabilisation standards we have adopted in our case follow the classic ABC pattern.[15]

The airway must be systematically isolated in patients with severe neurological, respiratory or haemodynamic involvement, as well as those in whom permeability cannot be permanently guaranteed because of trauma or severe burns to the facial bones, face or neck. The same procedure must be followed if the patient is agitated or requires high doses of sedatives or analgesics that could give rise to respiratory arrest. In most cases, in-flight intubation would necessitate a highly undesirable emergency landing.[16]

In critically ill patients, oxygen transport is compromised, and so, in many cases, is gas exchange in the lungs. Tissue oxygenation is a priority, and therefore, as an indispensable measure, we have to ensure that oxygen saturation is maintained close to 100% through conventional or high-flow masks or in nasal cannulae if the patient is not intubated. In patients undergoing mechanical ventilation special attention must be paid to airway pressure. The risk of pneumothorax must be minimised, especially in patients with a pattern of obstruction. Peak pressure, and especially mean pressure, must be as low as possible. The greatest risk to a patient on ventilation, apart from pneumothorax, is accidental extubation; special attention must be paid to the fixing of the endotracheal tube and any moving of the patient must be done with extreme care.

From the circulatory point of view, it is essential to have at least two intravenous lines and for at least one of them to ensure high flow infusion. Otherwise, the placement of a central catheter will be indicated, allowing for rapid expansion of volume when the need arises. One must try to achieve the maximum possible haemodynamic stabilisation, depending on the condition from which the patient is suffering, optimising blood volume or using vasoactive drugs. Although the minimum level of haemoglobin in stable patients is 8 g/dl, in critically ill patients it is advisable to set it at 10 g/dl, especially in cases of craneoencephalic trauma; PRBC (packed red blood cells) must therefore be infused until this is achieved.[17–21] The coagulopathy which tends to occur in these patients must also be stabilised as far as possible. Prothrombin time, partial thromboplastin time and platelet count are the values that must be monitored. The objective is to attain a prothrombin time >18 s, an activated partial thromboplastin time >60 s and a platelet count >100,000 with the administration of plasma and/or platelets.[22,23] Finally, it must be borne in mind that we can never transfer a patient with ongoing internal haemorrhage. Damage control surgery is essential in such cases to control the bleeding and make it possible to achieve haemodynamic stabilisation that will ensure a sufficient degree of haemodynamic stability during the transfer. If necessary, definitive surgery will be performed at the receiving hospital in a second phase.[24,25]

With respect to neurological status, patients with a Glasgow Coma Scale score <10 must be intubated, avoiding as far as possible continuous infusion of curare, which would prevent us from detecting possible convulsions or clinical signs of herniation during transport. In cases of craneoencephalic trauma, appropriate cerebral oxygenation and perfusion pressure must be maintained. Reduction of cerebral blood flow due to hyperventilation may aggravate post-traumatic ischaemia. For this reason we maintain a pCO_2 of between 35 and 40 mm Hg and oxygen saturation close to 100%. Hyperventilation must not be induced nor must manitol or hypertonic saline solutions be used as a preventive measure. Arterial blood pressure shall be kept, as far as possible, at normal levels, helping to maintain appropriate cerebral perfusion pressure; permissive hypertension is not recommended in these patients. By obtaining a cranial CT scan prior to transfer we will be informed of possible lesions that may give rise to increases in intracranial pressure during transfer. Finally, patients who have presented with convulsive seizures must be treated.

Even though the hospital care staff largely stabilised the patients in the series under review, the transport team had to apply various techniques before beginning the transfer in order to achieve the desired stabilisation objectives described in the previous paragraph. This explains the fact that on many occasions stabilisation took longer than the transport itself. The transport team carried out 24% of the intubations, 20% of the peripheral intravenous line placements, 17% of the central catheters and 71% of the pleural drains.[26] This last point is particularly significant. One must remember that atmospheric pressure during a helicopter flight is lower than at sea level. According to Boyle's law, this leads gases to expand, and the higher the flight altitude the greater the expansion. Therefore any pneumothorax, even if not under tension, must be drained beforehand.[27] Another point to be highlighted is that haemodynamic stabilisation is more demanding, as evidenced by the high rate of use of vasoactive drugs by transport teams, 46% of the total. Finally, it is important to note that transport of an unstable patient with internal bleeding was refused until a surgical operation had been performed. Specifically, a simple craneoencephalic trauma had been diagnosed. The transfer team observed a haemodynamic instability that was not attributable to the cranial trauma; a scan detected a ruptured liver, and an operation was therefore carried out prior to transport.

Checking the infusion pumps and the correct placement of drains, probes and intravenous drips before and after transport is crucial. Autonomy in medical gases and electricity must be tested beforehand, as well as the autonomous suction equipment. The transport ventilator parameters must be adjusted, on the basis of the prior ventilation settings in the hospital, according to blood gas values, just before beginning the transfer. It is advisable to take a chest X-ray to check the correct positioning of the endotracheal tube and the pleural drains once the patient has been placed on the trolley. Electrocardiogram, arterial oxygen saturation, respiratory frequency and arterial blood pressure must be continuously monitored. The resuscitation medication, manual ventilation equipment and defribillator, as well as the drugs that may potentially be needed according to the illness, must be kept to hand. Among the latter we would particularly emphasise sedatives, analgesics, neuromuscular blockers, anticonvulsants and vasoactive drugs.[28] The most important thing, however, is to be constantly attentive to the patient being monitored: to keep a constant check on his or her state, level of consciousness, colour, symmetry of ventilation, pulse and possible presence of alarming clinical signs. We must detect any change in stability, anticipate events and treat complications as soon as they arise. We have to bear in mind that an emergency landing may be required, depending on the procedures that have to be performed. We must warn the pilots about these circumstances so that they keep the flight as stable as possible and stay on the lookout for potential landing sites.[29]

Complications during transport

Any complication during medical transport, particularly by helicopter, is potentially serious. The difficulties of any transfer are increased by the limited space in the cabin. We want to emphasise, however, that although the overall rate of complications in transit was 22.9%, those that put the patient at grave risk and that we define as major represented only 5.1% of the total. As for minor complications, they amounted to 17.7%, in line with other articles published on adults.[30] However, although we have defined them as complications that we were able to resolve with minimal intervention, if they had not been noticed and consequently treated they could have put the patient in serious danger. It must be emphasised that in order for such situations to be easily controllable, they have to have been anticipated and the necessary means provided to resolve them. The line separating minor from major complications is precisely their prevention, even if it entails a greater degree of intervention during prior stabilisation.

Specifically, with regard to the airway, ventilation and oxygenation, the greatest risk of complications is accidental extubation or an unforeseen need for intubation. It is important to stress that one must be especially careful in this area and very rigorous in prior stabilisation. In our case, 38.1% of patients were intubated before transfer and we would highlight the fact that none needed to be intubated in flight. It is also worth mentioning that only one pneumothorax occurred while flying. This point reinforces the importance of detecting and draining air leaks before transport, even if they are not under tension, and ventilating patients at the lowest possible pressures. From the point of view of circulation, it is vital to have permeable venous access points that enable large flows of liquids to be infused. In our series, no lines needed to be placed in transit. It should be remembered that this last technique, and also intubation, are particularly difficult procedures to perform in flight and significantly compromise the patient.[31] It is worth emphasising that an emergency landing had to be made on only two occasions, one for ventricular fibrillation and one because of a cardiac arrest. In the latter case, the patient died.

Conclusion

Transport of critically ill paediatric patients between hospitals entails a potential risk of complications. Their treatment, if they occur, is especially difficult during transfer by helicopter. In order for it to be carried out in optimum conditions, two conditions have to be fulfilled: a high degree of specialisation in the care team and an adequate level of stabilisation at the sending hospital. Ensuring permeability of the airway, providing appropriate ventilation and optimising the level of cardiocirculatory stability are particularly important. In our series, 38.1% of the patients were intubated (24.3% by the transport team) and no patient required intubation during transfer. A total of 14 chest tubes were placed (71.4% by the escorts) and only one patient had a pneumothorax during the flight. Of the total of 495 intravenous line placements, 19.8% were carried out by the transport team and none were needed in transit. Vasoactive drugs were administered to 23.7% of the patients, 46.7% being instituted by the escorts. In no case did administration have to be initiated during the transfer.

In total, only 5.1% of the patients suffered a serious complication. We attribute this low rate of complications to correct stabilisation based on the standards adopted by the team.

Conflicts of interest

The authors have no conflicts of interest to declare.

Appendix A. [{(Transport team)}]

Paediatricians: E. Moliner; M.J. García; E. López; E. Turón; P. Febles; R. Morales; A. Torras; I. Guimerá; C. López; A. Sánchez; A. Scheibl; M. Tirado. Holders of university degrees in nursing: M. Rodríguez, D. Villegas, M. Vila, A. Partida, R. Pérez, A. Riba, G. Ortoneda, N. Macías, A. Pérez, N. Ferrer. Pilots: Iñaki Rul·lan, Santi Fuster, Richard Tizon, Sergi Galdón.

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