Anaesthesia / Early View

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Guidelines for safe transfer of the brain-injured patient: trauma and stroke, 2019

Guidelines from the Association of Anaesthetists and the Neuro Anaesthesia and Critical Care Society

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First published: 01 December 2019
https://doi.org/10.1111/anae.14866

This is a consensus document produced by expert members of a Working Party established by the Association of Anaesthetists of Great Britain and Ireland and the Neuro Anaesthesia and Critical Care Society. It has been seen and approved by the Board of Trustees of the Association and the Council of NACCS. It has been endorsed by: the Royal College of Emergency Medicine; the Royal College of Anaesthetists; the Intensive Care Societies in England, Ireland, Scotland and Wales; the Paediatric Intensive Care Society; the Society of British Neurological Surgeons; the British Society of Neuroradiologists; and the British Association of Stroke Physicians.

Summary

The location of care for many brain-injured patients has changed since 2012 following the development of major trauma centres. Advances in management of ischaemic stroke have led to the urgent transfer of many more patients. The basis of care has remained largely unchanged, however, with emphasis on maintaining adequate cerebral perfusion as the key to preventing secondary injury. Organisational aspects and training for transfers are highlighted, and we have included an expanded section on paediatric transfers. We have also provided a table with suggested blood pressure parameters for the common types of brain injury but acknowledge that there is little evidence for many of our recommendations. These guidelines remain a mix of evidence-based and consensus-based statements. We have received assistance from many organisations representing clinicians who care for these patients, and we believe our views represent the best of current thinking and opinion. We encourage departments to review their own practice using our suggestions for audit and quality improvement.

Recommendations

1. There should be designated consultants in referring hospitals and neuroscience units* with overall responsibility for the organisation, infrastructure and processes to enable safe transfer of patients with a brain injury.

2. Local guidelines should be drawn up between referring hospitals, neuroscience units and local ambulance services and should be consistent with these national guidelines.
3. The transfer of responsibility for the patient's care should be agreed by both parties.
4. Although transfer is often urgent, resuscitation and stabilisation of the patient should be underway before transfer; avoid transfer of a hypotensive or hypoxic patient.
5. Patients with a Glasgow Coma Scale (GCS) ≤ 8, a significantly deteriorating conscious level, for example, a fall in GCS of two points or more, or a fall in motor score of one point or more, and requiring transfer should undergo tracheal intubation and mechanical lung ventilation.
6. The Working Party has used a consensus technique to devise recommendations on blood pressure targets (provided in a table).
7. Patients with acute ischaemic stroke for thrombectomy should be transferred without delay; those with anterior circulation stroke rarely need airway intervention.
8. Patients with a brain injury should be accompanied by a clinician with appropriate training and experience in the transfer of patients with acute brain injury.
9. Monitoring during transport should adhere to published guidelines.
10. The transfer team should be in possession of a mobile phone for urgent communication.
11. Education, training and continuous audit are crucial and help to maintain standards of transfer.

*The term acute neuroscience unit is taken to include neurology, neurosurgery, neuro anaesthesia, neurocritical care, diagnostic and interventional neuroradiology

What other guidelines and statements are available on this topic?

Although guidelines on the management of brain-injured patients (particularly traumatic brain injury) are available, practical advice for their safe transfer is not.

Why was this guideline developed?

In 1996, the Association of Anaesthetists and the Neuro Anaesthesia Society (NASGBI) published *Recommendations for the Transfer of Patients with Acute Head Injuries to Neurosurgical Units*. In 2006, an update (*Recommendations for the Safe Transfer of Patients with Brain Injury*) was published. This is an update of guidelines that are now 13 years old.

How and why does this statement differ from existing guidelines?

This update was conceived to take account of recent developments in the management of multiply-injured patients (including permissive hypotension during resuscitation) and in those with acute ischaemic stroke by endovascular thrombectomy. We have included new

suggestions on the management of blood pressure, based on the consensus view of the Working Party members.

Introduction

The Working Party believes, empirically, that high-quality transfer of patients with a brain injury will be associated with a better outcome.

Patients with an acute brain injury (which includes traumatic and non-traumatic causes such as stroke) often receive their initial treatment at a local hospital, which may not have a neurosciences unit. Patients with major trauma in England will be triaged to a major trauma centre that will have an associated neurosciences unit. However, patients with an isolated head injury, those with undiagnosed major trauma, those without trauma (such as subarachnoid haemorrhage, intracerebral haemorrhage or stroke), and those who deteriorate while in hospital will require transfer between hospitals. In some regions, critical care networks and transfer groups have been established, but elsewhere patients with brain injury will require staff within a local unit to arrange and undertake a transfer. Similarly, transfers of patients within a hospital should be given the same care and planning as transfers between hospitals.

Transfer of patients with a brain injury is potentially hazardous if poorly executed. Patients can come to harm and long-term neurological outcome may be adversely affected. This can be avoided if sound principles are applied. Secondary brain injury is a consequence of cerebral hypoxia due to either reduced oxygen supply (i.e. raised intracranial pressure (ICP), hypotension or hypoxaemia) or increased oxygen demand (i.e. hyperthermia or seizures). Most principles of safe transfer are common to all seriously ill patients, but these specific risks apply to those with acute brain injury.

In 2015, a Care Quality Statement from the Society of British Neurological Surgeons advised: "*Admission to a regional neurosurgical unit for life-saving, emergency surgery should never be delayed. Neurosurgical units should not refuse admission for patients requiring emergency surgery referred from their catchment population. The lack of critical care beds should not be a reason for refusing admission for patients requiring urgent surgery. Surgery remains the priority and the appropriate post-operative critical care resources should be identified after surgery, either in the lead neurosurgical unit or in another unit*" [1]. Although no precise time limit has been set between injury (leading to an expanding haematoma) and surgery, a maximum of 4 h is the commonly accepted target (although not evidence-based) as it is clear that the sooner the haematoma is evacuated, the better for the patient. Similarly, patients with acute ischaemic stroke require mechanical thrombectomy as soon as safely possible. The Working Party recommends that networks should work towards to auto-acceptance criteria for brain-injured patients (similar to those used within trauma networks).

Recent developments in the management of stroke

Stroke is the third leading cause of death and disability in the developed world. Improving outcomes for acute stroke patients offers major benefits both to individual patients and society as a whole. Advances in care such as endovascular coiling for acute subarachnoid haemorrhage, mechanical thrombectomy for acute ischaemic stroke [2] and decompressive craniectomy for malignant middle cerebral artery infarction [3], have resulted in the need for many patients to be urgently transferred to specialist neuroscience centres. The treatment of with acute ischaemic stroke is time critical. Currently, the standard treatment for acute ischaemic stroke in patients presenting with symptoms up to 4.5 h after onset is intravenous (i.v.) thrombolysis using tissue plasminogen activator [4]. Mechanical thrombectomy is recommended in addition to i.v. thrombolysis to treat patients with demonstrable proximal artery occlusions in the anterior circulation who can be treated within 24 h of symptom onset [2], [5], [6]. If i.v. thrombolysis is contra-indicated (e.g. in a warfarin-treated patient with therapeutic anticoagulation) mechanical thrombectomy is recommended as the first line of treatment [6].

Organisational aspects

These guidelines are provided for those responsible for planning, managing and undertaking transfer of brain-injured patients. The aim is to provide not only practical guidance for ensuring safe transfer of individual patients but also to assist in local negotiations when establishing new or improving existing transfer arrangements.

For avoidance of doubt, where this document refers to anaesthetic departments, this is taken to include the hospital's critical care department.

The safe transfer of patients with brain injuries requires an effective partnership between the referring teams, the regional neurosciences or stroke unit, and the local ambulance service. As a result of the introduction in England of major trauma networks and trauma unit bypass tools in 2012 [7], there are potentially a smaller number of patients with traumatic brain injury requiring secondary transfer to neuroscience centres. As noted above, developments in the management of acute stroke have led to an increase in the number of stroke patients requiring secondary transfer for specialist care.

Every hospital that receives patients with serious brain injuries should have facilities for resuscitation and diagnosis, including 24 h access to CT imaging. Appropriate staff and equipment should be available at all times to ensure a safe transfer to the neuroscience unit when necessary. Although it is the responsibility of the referring hospital to ensure safe transfer of the patient and decide whether tracheal intubation and ventilation are required, planning for the transfer should be shared between the referring hospital and the receiving unit. There should be a designated consultant within the hospital who has overall responsibility for secondary transfers and a consultant at the neurosciences unit who has overall responsibility for receiving transfers. The time to undertake these duties should be recognised in job plans.

The responsibilities of the designated consultant for transfers include logistics, training, audit and planning between the parties involved. Rotas of doctors and other healthcare staff involved in transfers should take account of this work to allow staff of adequate seniority to be released from other duties. Managers should recognise that there are significant resource implications to the transferring hospital's on-call anaesthetic team.

Transfer agreements

Local plans should be agreed between the referring hospitals and the neurosciences unit in advance. They should be subject to regular review and audit which should be the responsibility of the specialist centre. The anaesthetic department should be involved in developing these local plans and agreements and ensuring they are consistent with established national guidelines. Guidelines do not replace clinical judgement but provide a safe framework within which judgement can be exercised and which can form the basis for audit and governance. Any governance problems should be brought to light and discussed openly among the network partners.

Agreements should include:

- Which patients should be referred and what information should accompany them (including details of how to ensure timely essential image transfer);
- Which patients require immediate emergency transfer (acknowledging that time-sensitive brain-injured patients should be prioritised appropriately);
- Who is the primary contact responsible for accepting the patient and how to contact them with alternatives if this primary contact is not immediately available;
- What to do if there are unexpected clinical changes before, or during, the transfer;
- The preparations and arrangements for the journey itself so that there are no unnecessary delays;
- How to contact the ambulance service including clear information regarding the urgency of the transfer required, the necessary qualifications of the ambulance crew and the nature of the vehicle required (e.g. ICU equipped, bariatric);
- The standards of care expected for the patient and the level of education/training required by the accompanying team;
- Clear details as to where the patient is to be received (e.g. ITU/theatre suite/radiology suite/ward/Emergency Department etc.);
- The point at which the responsibility for the patient is transferred from the referring to the receiving team.

Most transfers will be by land ambulance, but, for transfers over longer distances, local plans may include transfer by air. Many critical care networks have reached consensus with local ambulance providers to ensure that all Trusts have common standards for transfer equipment. These developments are highly desirable, and likely to result in better organisation and delivery of patient care.

Staffing requirements

Staff shortages or the need to cancel routine work should not allow transfers of these patients to be compromised or substandard. The Working Party is aware that some centres use Advanced Critical Care Practitioners for chosen transfers. The type of clinician will, to some extent, be contingent on the dependency of the patient and local factors. A critically ill patient with an acute brain injury must be accompanied by a clinician with suitable training, skills, competencies and experience of brain injury transfers. They should be able to independently initiate, administer and modify pharmacology, physiology and lung ventilation to minimise secondary brain injury. In addition, they should be competent to perform independent drug-assisted tracheal intubation of brain-injured patients during the transfer if the situation necessitates it.

Retrieval teams have been set up in some regions and are of particular importance in paediatric practice. However, the speed of transfer required for brain-injured patients may not permit a team to travel from the neuroscience centre; any unit receiving children with a brain injury should have a plan in place to undertake such a transfer (with appropriate paediatric equipment).

A trainee is working under distant supervision if there is no senior colleague/consultant travelling with them. Access to consultant advice, by mobile phone or equivalent, is essential. Changes in working patterns may reduce the availability of trainees for transfers and consultant time for transfers should be built into manpower projections. Shift arrangements should be taken into account when deciding who should accompany the patient. The Working Party believes a dedicated trained assistant should assist the clinician. This might be an operating department practitioner, an anaesthetic trained nurse, an ICU nurse or an Advanced Critical Care Practitioner.

Employers should ensure there is appropriate medical indemnity insurance for such transfers. In addition, the Association of Anaesthetists recommends that doctors are members of a medical defence organisation. Adequate death and personal injury insurance should also be provided for the members of the transfer team by the employer; existing employer insurance may be inadequate and local arrangements should be clarified. Such cover is a benefit of Association of Anaesthetists membership. Currently this cover is up to £1m.

Stroke

The majority of patients with anterior circulation stroke will not need to be accompanied by an anaesthetist. However, a significant proportion of patients with malignant middle cerebral artery infarction, posterior circulation acute ischaemic stroke and subarachnoid haemorrhage will require critical care intervention and appropriate support for transfer.

Education and training

Good practice depends on sound education, adequate resources of expertise, time for training and a commitment to quality. The consultant responsible for the organisation and oversight of interhospital transfers should ensure, and facilitate, good educational standards and arrangements for transfers. A fundamental requirement is that every member of staff likely to be involved in the transfer of seriously brain-injured patients has undergone training in the theoretical and practical aspects of transport medicine (see Table 1) [8]. The setting in which this education is provided will vary. Attendance at a simulator-based course may be a suitable educational environment. Learning opportunities will range from mandatory induction courses for new hospital staff to multidisciplinary training courses on transfer medicine. The latter are now run in a number of centres and may be particularly appropriate for consultants responsible for developing and maintaining standards for transfers. The development of competency in the management of the critically ill, but stable, ventilated patient requiring interhospital transfer is a core learning outcome at the intermediate level of specialty training in anaesthesia.

Table 1. Components of training for transfers

Principles of managing a patient with an acute brain injury
Principles of ATLS or the European Trauma Course
Adverse physiological changes associated with moving a patient
Manual handling
Practical aspects of working in an ambulance or aircraft
Knowledge of the equipment and drugs used in transfer
Legal and safety aspects of transfer
Communication and other non-technical skills such as team working

Paediatric regional transport teams are involved in outreach education meetings involving case discussions and paediatric stabilisation training days, which allow multiprofessional, table-top exercises and simulation training to ensure safe transfers.

Preparation for transfer

The decision to transfer a patient with a brain injury should be made by senior medical staff at the referring hospital in consultation with senior staff at the neurosciences unit. Appropriate resuscitation and stabilisation of the patient before transfer is the key to avoiding complications during the journey.

When a request is made for an ambulance to transfer the patient (including those with acute ischaemic stroke), the dispatcher should be told the patient has a life-threatening emergency.

Equipment and drugs

The patient should receive the same standard of monitoring during the transfer as they would receive in their referring unit [9]. The transfer team should be familiar with all of the equipment and drugs in the transfer kit and the transfer vehicle.

Transfer equipment should only be used for transfers. It should be serviced in accordance with the manufacturer's guidance and checked regularly, with a further test immediately before the transfer. If the ambulance's ventilator is to be used, then it should be checked before departure, as should the ambulance oxygen supply, suction apparatus and battery charge status. It is advisable before purchasing any new equipment to consult the local ambulance service to ensure that it is compatible with the oxygen and power supply in their vehicles. Portable equipment will need regular battery replacement and will have a shorter life expectancy than static equipment.

Essential equipment to go with the patient in the ambulance

The following equipment should be readily available, purpose-designed, dedicated for transfers and be stored in a suitable container that should have some form of seal, which when broken indicates that the equipment has been used and requires restocking and checking:

A portable mechanical ventilator with airway pressure, minute volume monitor and disconnect alarm.

Oxygen; an adequate supply for the journey, including unforeseen delays. Oxygen requirements for the journey including possible delays should be estimated and include driving gas requirements of the ventilator. The minimum reserve of oxygen should be 1 h, or twice the estimated journey time, whichever is longer. If transfer times are very long, it may be necessary to arrange for back-up oxygen supplies to be made available en-route.

A portable, battery powered multifunction monitor including ECG, invasive blood pressure monitoring (preferred if time allows), non-invasive blood pressure (NIBP) (as an alternative), pulse oximetry and capnography.

Other equipment; glucometer (if receiving insulin), battery-powered syringe pumps, battery-powered i.v. volumetric pumps, appropriate intubation equipment, self-inflating

bag, valve and mask, venous access equipment, chest drain or equipment for finger thoracostomy (if major trauma), DC defibrillator, insulating blanket, torch (to assess pupils), a means to record physiological variables and the administration of drugs/fluids during the transfer.

An adequate supply of essential drugs to go with the patient (including an allowance for unanticipated delays) (see Table 2); pre-filled syringes are preferable if available.

Table 2. Drugs to accompany transfer of patients with a brain injury

Hypnotics, for example, propofol or midazolam
Neuromuscular blocking agents, for example, suxamethonium, atracurium or rocuronium
Opioid analgesics, for example, alfentanil, fentanyl or a remifentanil infusion
Anticonvulsants, for example, a benzodiazepine or thiopentone, and an anti-epileptic, for example, levetiracetam
Mannitol 20% or hypertonic saline
Vaso-active drugs, for example, ephedrine, metaraminol, noradrenaline, labetalol
Resuscitation drugs (as in hospital resuscitation boxes)
Intravenous fluids (usually 0.9% saline)
Cross-matched blood (e.g. in trauma patients)

Communication equipment; it is essential that the transfer team should be able to communicate easily with the designated consultant or deputy in the referring hospital and with the neurosurgical team during the transfer by use of a mobile phone (ideally with emergency numbers pre-programmed into the memory).

Paediatric equipment; the transfer of paediatric patients will require size-specific equipment (and staff experienced in the transfer of critically ill children).

Monitoring

In all cases, monitoring commenced before the transfer (and used continuously during it) should include GCS, pupillary size and reaction to light, ECG, pulse oximetry, invasive blood pressure monitoring via an arterial line is preferable (however, urgent transfer should not be delayed for insertion of an arterial cannula and NIBP may be a satisfactory alternative, such as in acute ischaemic stroke), capnography and urine output (urinary catheter). The Working Party considers that the development of portable, battery-powered processed EEG (pEEG) devices will be beneficial for the safe transfer of patients who are sedated and have received a neuromuscular blocking agent [10].

Physiological status

Each type of brain injury may require specific physiological targets (see Table 3); however, a fundamental requirement before transfer is to ensure satisfactory oxygen delivery and an adequate blood pressure, with PaO_2 ≥ 13 kPa (but avoid hyperoxia, especially in acute ischeamic stroke), and $PaCO_2$ between 4.5 and 5.0 kPa (N.B. there is no good evidence base for precise limits).

Table 3. Physiological variables and fluids for transfer of brain-injured patients. Of note, there is little high-quality evidence to support particular values and this table is the product of discussion and consensus between members of the Working Party. Where possible, the BP targets reflect the recommendations of the European Trauma Course

	Traumatic brain injury (incl. traumatic subarachnoid haemorrhage)	**Intracerebral haematoma/haemorrhagic stroke**	**Acute ischaemic stroke**	**Spontaneous subarachnoid haemorrhage**
Systolic blood pressure (mmHg)	> 110 (and MAP > 90 mmHg) < 150	< 150 if within 6 h of onset of symptoms and immediate surgery not planned	> 140 < 185 &!#6;(if candidate for/has received i.v. thrombolysis); or, < 220 (if thrombolysis is contraindicated and being transferred for thrombectomy)	> 110 < 160

Tracheal intubation

Appropriate respiratory function should be established before commencing the transfer. The need to intubate the patient's trachea and start mechanical lung ventilation may be clear, but if it is in doubt then input from senior, experienced clinicians is required. Tracheal

intubation during a transfer is difficult. The indications for tracheal intubation before transfer are given in Table 4.

Suggested technique for tracheal intubation:

Brain-injured patients may have poor respiratory effort and may require their breathing to be supported (e.g. gentle bag-mask ventilation) to facilitate adequate pre-oxygenation 11.

Use an i.v. induction agent combined with an opioid to ablate the sympathetic response to intubation, and neuromuscular blockade to avoid an increase in ICP 12.

For trauma patients, ketamine may be the best choice of induction agent, as the preservation of systemic arterial blood pressure will outweigh any theoretical concern about cerebral stimulation 13; modify dose in unstable patients.

Neuromuscular monitoring, attached before induction, will indicate that neuromuscular blockade has been achieved before intubation.

Use a laryngoscope (or videolaryngoscope) with which you are familiar (similar proviso for other equipment used for difficult intubation).

Use the target blood pressure values summarised in Table 3. A transduced direct (invasive) arterial pressure waveform (with the transducer placed at the level of the tragus) will facilitate a stable haemodynamic induction; if time does not allow for invasive monitoring before intubation, NIBP measurement at 1-min intervals is recommended for the peri-induction period.

Table 4. Indications for tracheal intubation in brain-injured patients

GCS ≤ 8
Significantly deteriorating conscious level (e.g. a fall in GCS of two points or more, or a fall in motor score of one point or more)
Loss of protective laryngeal reflexes
Failure to achieve PaO_2 ≥ 13 kPa; but, a lower target can be accepted in patients with AIS (aim for peripheral oxygen saturation ≥ 95%)
Hypercarbia ($PaCO_2$ > 6 kPa)
Spontaneous hyperventilation ($PaCO_2$ < 4.0 kPa)
Bilateral fractured mandible
Copious bleeding into the mouth (e.g. from skull base fracture)
Seizures

Prevent aspiration of gastric contents; use a rapid sequence induction technique with manual in-line stabilisation of the cervical spine following trauma, maintenance of head-up tilt and use of cricoid pressure if there is a risk of aspiration.

A typical drug regime for induction:

High-dose fentanyl (3–5 $\mu g.kg^{-1}$), alfentanil (10–20 $\mu g.kg^{-1}$) or start a target-controlled infusion (TCI) of remifentanil (Cpt ≥ 3 $ng.ml^{-1}$); use lower doses in unstable patients (e.g. multiple trauma).

Induction agent and dose chosen to ensure maintenance of adequate mean arterial pressure (MAP); the use of a TCI regime at induction will facilitate sedation for subsequent transport. Ketamine 1–2 $mg.kg^{-1}$ may be useful in haemodynamically unstable patients (e.g. after trauma).

Neuromuscular blockade with suxamethonium 1.5 $mg.kg^{-1}$ or rocuronium 1 $mg.kg^{-1}$.

A vasoconstrictor (e.g. ephedrine or metaraminol) should be available to treat any immediate hypotension. Further induction agent or opioid is given if the patient is hypertensive, and the tracheal tube is secured. Occlusion of venous drainage is avoided by taping the tube in place instead of using ties.

Blood pressure management

A patient who remains hypotensive despite resuscitation should not be transported until the causes have been identified and, if possible, the patient stabilised. The role of 'damage control surgery' and other techniques to manage major haemorrhage will depend on expertise and facilities at the presenting unit but, in general, correction of major haemorrhage takes precedence over transfer. It is important that these measures are not omitted in an attempt to speed up transfer of the patient, as resultant complications may be impossible to deal with once the journey has begun. Persistent hypotension will adversely affect neurological outcome [14]. When other causes of hypotension have been excluded, consider the judicious use of inotropes or vasopressors (e.g. metaraminol infusion) to offset the hypotensive effects of sedative agents. Blood pressure targets are described in Table [3]. Hypertension may be a sign of worsening neurological status, or of inadequate sedation.

Other preparations before the transfer (and see Appendix [S1] in Supporting Information):

Arterial blood gases: check oxygenation, validate end-tidal carbon dioxide by estimation of A-a gradient, electrolytes and blood glucose (aim for 6–10 $mmol.l^{-1}$);

Major trauma patients will also have had chest, abdomen, pelvis and cervical spine CT imaging (in addition to CT head) obviating the need for additional radiographic images; ensure the images have been sent to the receiving unit;

Haematology: full blood count and coagulation screen;

After significant haemorrhage, blood, fresh frozen plasma (FFP) and cryoprecipitate transfusion and tranexamic acid may be required during the transfer – but the patient should only be moved if stable;

An intercostal drain should be inserted if a clinically significant pneumothorax is present. Underwater seals should normally be replaced by leaflet valve (Heimlich type) drainage systems and chest drains should not be clamped;

Where patients are being transferred within a neurosurgical centre with an external ventricular drain in situ, advice should be sought from the neurosurgical team. There is danger of cerebrospinal fluid overdrainage if it is kept too low, and clamping may be warranted for short periods;

Core temperature monitor (e.g. bladder or oesophageal); if the patient is hypothermic use active warming before transfer and keep insulated in the ambulance; aim for normothermia (36–37°C);

Confirm correct placement of tracheal tube (and gastric tube, if present);

If the patient has had a seizure, loading with anticonvulsant agents (e.g. levetiracetam 1 g [some units use 20 $mg.kg^{-1}$] or phenytoin 20 $mg.kg^{-1}$, max. 2 g) should be undertaken before transfer.

Acute ischaemic stroke

Resuscitation and stabilisation before transfer is essential but all efforts should be made to avoid delays. Transfers are time critical [6]; in particular, mechanical thrombectomy should be performed as soon as possible after its indication is confirmed (within 6 h when possible; however, recent trials have demonstrated benefit up until 24 h in selected patients). Intubation is not required if adequate oxygenation and ventilation can be maintained with or without supplemental oxygen, and this is the usual case in patients with anterior circulation acute ischaemic stroke. Supplemental oxygen should not be prescribed routinely. Inspired oxygen should be titrated to maintain peripheral blood saturation at 93–98% [6]. Patients with acute ischaemic stroke who are otherwise stable do not usually need a medical escort.

Preparing the transfer team

The transfer team should be relieved of all other duties, be appropriately dressed, equipped and insured. Ideally the same team should be involved in the initial resuscitation, management and preparation of the patient. If this is not possible, they should receive a formal handover from the resuscitation team. Good verbal and written communications are vital. This is especially so at the time of referral and when a patient is handed over at the end of the transfer. The Working Party recommends the use of a checklist (see Appendix S1 for an example) before departure. All notes (or photocopies) and blood results should accompany the patient.

Table 5. Mean arterial blood pressure targets in children with a brain injury

Age	Mean arterial blood pressure (mmHg)
< 3 months	40–60
3 months–1 year	45–75
1–5 years	50–90
6–11 years	60–90
12–14 years	65–95

The relevant duty consultant (anaesthetist/intensivist/stroke physician/acute care (emergency) physician/neurosurgeon) in the receiving hospital should be made aware of the planned transfer. The transfer team should be told where to go in the receiving hospital. They should be equipped with a mobile telephone to enable contact with the neurosciences unit and their base hospital en-route in case of clinical deterioration.

The patient's relatives should be notified about the transfer and the reasons for it, by the referring hospital. They should be informed of the ultimate ward/ICU destination. They should not normally accompany adult patients in the ambulance.

Care during the transfer

During transfer, patient management will be centred on maintaining oxygenation and adequate blood pressure, and minimising rises in ICP. As far as possible, a smooth journey (without marked acceleration and deceleration) will have less impact on a patient with an injured brain. A patient who is physiologically stable before departure is more likely to remain so for the duration of the transfer, although there is still the need for constant vigilance and prompt action to deal with complications. If, despite thorough preparation, there is a need to perform any procedure during the transfer the ambulance may need to be brought to a halt. When the ambulance is moving, transfer staff should remain seated with a seat belt in place.

Monitoring

Monitoring as detailed above should be continued. All monitors should be securely mounted so they cannot fall on to the patient during transfer or cause injury to ambulance occupants in the event of an accident. A record of vital signs and neurological status (such as pupil size and responses) should be maintained during the transfer. This may be aided by the electronic memory in monitors. The development of standardised documentation is

encouraged, and many critical care networks have developed local transfer documentation. The referring team should keep a copy of the transfer record for audit purposes.

Maintenance of sedation

After tracheal intubation, appropriate drugs should be used to maintain sedation and analgesia (usually by continuous infusion; TCI may be preferred if available), and neuromuscular blockade. If an agent other than propofol has been used for induction, care should be taken if subsequently instituting a TCI regime, so as not to precipitate a fall in blood pressure. Processed EEG monitors may be of use for titration of sedation to effect [15].

Positioning

The patient should be transferred onto the transport trolley/stretcher, properly secured and padded with due regard to any possible spinal injury. The patient should be positioned with a 20–30° head-up tilt. The use of ambulance trolleys that allow this degree of tilt, while maintaining spinal immobilisation, is encouraged.

Mechanical lung ventilation

If the trachea is intubated, the patient's lungs should be ventilated with the aim of achieving PaO_2 of ≥ 13 kPa and $PaCO_2$ of 4.5–5.0 kPa. If there is clinical or radiological evidence of raised ICP with impending uncal herniation, hyperventilation ($PaCO_2$ not less than 4 kPa) is justified for short-term use, together with other methods of decreasing ICP (e.g. mannitol [0.5 $g.kg^{-1}$] or hypertonic saline [2 $ml.kg^{-1}$ of 3% saline], or a bolus of sedative drugs).

Inspired oxygen should be guided by blood gas estimations before departure, and end-tidal carbon dioxide should be monitored continuously. An estimation of the A-a gradient may help guide ventilation during transfer. Even short periods of hypoxia should be avoided and a minimum of 5 cmH_2O of PEEP should be used to prevent atelectasis; PEEP up to 10 cmH_2O does not adversely affect cerebral perfusion.

Fluid and blood pressure management

Blood pressure targets are summarised in Table 3. All invasive (direct) arterial blood pressure measurements should be measured with the transducer at the level of the tragus (including when the patient is positioned head-up).

The aims of fluid management in the early stages of patients with traumatic brain injury are to reverse hypovolaemia, avoid hypotension and maintain cerebral blood flow, so limiting cerebral ischaemia (and the potential for subsequent cerebral oedema). Hypovolaemic brain-injured patients do not tolerate transfer well and hypotension will adversely affect neurological outcome. If fluid resuscitation is not needed, cautious use of isotonic fluids to maintain hydration while preventing volume overload is appropriate during transfer. Intravenous fluids used in brain injury should be isotonic in terms of osmolality (not

osmolarity) to prevent an increase in brain water. The only commonly available isotonic crystalloid solution is saline 0.9%, and this is therefore the current crystalloid of choice in brain injury 16. The use of albumin or other synthetic colloid is not recommended in the early management of brain-injured patients. Gelatins, Ringer's lactate (compound sodium lactate) and Ringer's acetate are hypotonic when real osmolality (mosmol.kg^{-1}) rather than theoretical osmolality (mosmol.l^{-1}) is determined, and should be avoided 17.

Hypertension should be managed by increasing sedation and use of small boluses of labetalol. Management of hypotension, after correction of hypovolaemia or excess sedation, should be by small bolus of an α-agonist followed by an infusion (e.g. metaraminol, or noradrenaline (the latter administered only via a central venous catheter)).

Traumatic brain injury

In isolated TBI, a mean arterial pressure ≥ 90 mmHg and a systolic pressure ≥ 110 mmHg (but less than 150 mmHg) is aimed for. Transfer of a patient who is hypotensive and actively bleeding should not be considered. In the context of trauma and brain injury, hypotension should be assumed to be due to haemorrhage and the bleeding should be controlled before transfer. Correction of major haemorrhage takes precedence over transfer.

The role of permissive hypotension during resuscitation of multiply-injured patients with a traumatic brain injury should only be considered in exceptional circumstances. Whenever possible, such cases should be escalated to the relevant major trauma network or critical care network for discussion.

Spontaneous intracerebral haemorrhage

Many patients with intracerebral haemorrhage are elderly and receiving antithrombotic or anticoagulant therapy. This should be rapidly reversed while limiting fluid volumes (e.g. using prothrombin complex concentrate, not FFP, in addition to vitamin K to reverse warfarin). Patients who present within 6 h of the onset of symptoms with a systolic blood pressure > 150 mmHg should have their blood pressure reduced if immediate surgery is not planned 4, 18. There are no specific recommendations on fluid therapy in intracerebral haemorrhage.

Acute ischaemic stroke

Most stroke patients are euvolaemic at the time of their neurological event and are unlikely to require volume resuscitation per se. However, oral intake is often reduced afterwards, and i.v. maintenance fluids should be commenced.

Hypertension is present in the majority of patients with stroke. Blood pressure should be kept < 185/110 mmHg in patients with acute ischaemic stroke who are candidates for, or who have received, intravenous thrombolysis 4. Hypotension should be avoided; although there is no evidence for a precise target, the Working Party believes a systolic pressure

< 140 mmHg could be detrimental. If necessary, fluids and vasoconstrictors may be used to raise the blood pressure 19. For those who have a contra-indication to thrombolysis but are being transferred for thrombectomy, blood pressure should be controlled if the systolic pressure is > 220 mmHg.

Spontaneous (aneurysmal) subarachnoid haemorrhage

During transfer, the haemodynamic goal in a patient with an unsecured aneurysm is to maintain euvolaemia. The Working Party believes the systolic blood pressure should be kept < 160 mmHg but hypotension (systolic < 110 mmHg) be avoided. Most patients will not be hypovolaemic initially but may become dehydrated if they develop diabetes insipidus. Occasionally, hypotension may be due to cardiac complications and inotropes may be required 20.

Arrival and handover

Staff at the neurosciences unit should be immediately available to receive a comprehensive handover following which they assume responsibility for the patient's care. The Working Party recommends the use of a 'hands-off' handover (temporarily removing the transferring doctor from hands-on care of the patient while describing the patient's history, examination, results of investigations and clinical course to the receiving team). Medical notes and a copy of the transfer record should be left with the receiving staff.

The neurosciences unit should be prepared to provide the transfer team with refreshments. A protocol should be established to ensure the immediate return of the referring team with their equipment to their hospital. Often a contract exists with a local taxi firm for this purpose. Personal injury insurance should also cover the return journey.

Additional information for paediatric transfers

With the centralisation of intensive care services for children, 10 specialist paediatric transport services cover the UK at present. These services contribute to regional education and training of clinical staff in the improvement of recognition, resuscitation and stabilisation of critically ill children. They perform the majority of all interhospital transfers 21, with increasing evidence that such transfers are associated with better outcomes 22. However, for a small sub-group of patients with specific conditions, a time-critical transfer from the referring hospital, by the local team, is appropriate 23:

- Extradural haematoma;
- Acute subdural haematoma with mass effect;
- Obstructive hydrocephalus – intracranial haemorrhage, blocked VP shunt, etc.;
- Acute ischaemic stroke requiring urgent thrombolysis 24;

Subarachnoid haemorrhage;

Malignant middle cerebral artery infarction.

The same principles of practice and understanding of physiology with appropriate responsive management remain valid. There are, however, some differences that require specific knowledge and consideration.

There should be a pre-determined pathway for referral and transfer of brain-injured children developed in agreement by the regional transport service, regional trauma network and the regional neurosciences network.

This pathway is triggered by a referral made to the regional transport service following which the most appropriate method of transfer to the neurosurgical centre or PICU should be identified according to the clinical situation, stage of stabilisation, time of the day, the availability of the specialist transfer team and the distance of the referring hospital to the paediatric neurosurgical centre 25. The regional transport service will, for time-critical transfers, take over the task of getting the patient accepted by the neurosurgical team ensuring appropriate pathways are triggered at the receiving hospital. Communication between the transferring team and the regional transport service should be maintained.

The team transferring the child will ideally include an anaesthetist with regular paediatric elective lists or previous paediatric training, skills, competencies and experience of brain injury transfer. Where this is not possible, discussion with the local paediatric team should help in determining the best transfer team configuration with consideration of an accompanying paediatric trained nurse. A transfer checklist is helpful to ensure safe and time efficient transfer of these patients to a centre for definitive care (see Appendix S2 in Supporting Information).

Age-appropriate equipment (ventilator, monitoring etc.) should be available to the transferring team particularly for 2- to 10-kg children. The necessary equipment should be stocked in a paediatric transfer bag that is regularly checked and replenished and always available to be taken on intra- and interhospital transfers.

Children will need to be secured to the ambulance stretcher with multi-point age/body weight appropriate harness restraints.

Age-specific physiological normal ranges apply in children. Mean arterial blood pressure targets to maintain cerebral perfusion pressure are provided in Table 5 (as a general rule the MAP should be targeted at least 10 mmHg above the normal MAP range for age to take into account the increase in ICP). Age-specific emergency drugs and physiological parameters calculator are available from most paediatric transport services, or as a handheld app such as ‘Paediatric emergency drugs’ (iPhone and Android platforms by STRS/UBQO)

Children may have traumatic brain injury with intracranial haemorrhage without an appropriate history in the case of non-accidental injury. This should always be considered

in a child with neurological presentation. In children with non-accidentally inflicted head injury, unrevealed bleeding from solid organ injury should be considered in a haemodynamically unstable child.

Before induction of anaesthesia in a brain-injured child, it is wise to consider the use of a bolus of hypertonic saline (2.7–3%, 2–3 $ml.kg^{-1}$) to avoid an associated rise in ICP during predictable PCO_2 rise while performing laryngoscopy (i.e. apnoea), and to prevent the potential associated fall in blood pressure related to opioids and induction agents.

Children and young adults have relatively less available space around the brain during the brain growth period (until the age of 20), and small changes in intracranial volume have potentially dramatic clinical consequences. Osmotherapy (preferably hypertonic saline boluses or mannitol 20%) should be available and accompany the child and team during transfer. Indications for osmotherapy are summarised in the transfer checklist (see Appendix S2 in Supporting Information).

Young children are more rapidly prone to hypoglycaemia. Blood glucose should be measured, recorded and managed in the normal range using isotonic saline solution with added glucose (either 5% or 10% depending on the clinical need) as maintenance fluid (with a 50–60% restriction on standard rates of administration) during transfer.

In a child with obstructive hydrocephalus, in the setting of a blocked VP shunt with signs of raised ICP before transfer, discussion should be held with the neurosurgical team regarding sterile aspiration of the VP shunt reservoir (5–10 ml removed using a butterfly needle and three-way tap).

Acceleration and deceleration in a fast-moving emergency vehicle may have profound effects on an unstable child's haemodynamics with acceleration causing systemic hypotension and deceleration causing ICP spikes. Both are deleterious to a child's neurological condition. There should be a discussion between the clinical team and the ambulance technician to determine an appropriate driving style to ensure stability of a patient during an urgent transfer.

The eyes of a child with a neurosurgical emergency should not be taped closed (in order to permit regular pupillary examination); however, attention to corneal drying should be addressed with regular moisturising eye drops, or saline if this cannot be achieved.

Where possible (and space allows) a parent should be asked to accompany the child in the ambulance. This requires the parents to adhere to the rules set by the team for transfer. The parent should be pre-warned of anticipated instability and even death of the child. The presence of a parent means that consent for surgery can be taken at the receiving institution without delay. The presence of the parent in the ambulance is a team decision.

Audit and quality improvement

It is important to involve those who care for these patients (and their transfers) in regular intra- and interdepartmental audit. This will include emergency department personnel, anaesthetists, critical care staff, paramedics, etc. Participation of the neurosciences unit in such audit is particularly valuable. In particular, the quality of transfers should be audited (see Table 6), and critical incidents recorded and reviewed. Such information is invaluable in refining and improving local transfer protocols.

Table 6. Suggested metrics for local audit/quality improvement

Clinician accompanying patient is suitably trained in transfers
Patient's trachea intubated if GCS ≤ 8 before departure
If intubated, capnography used during the transfer and all values 4–5 kPa
Arterial blood gas measurement performed before departure
Blood sugar 6–10 $mmol.l^{-1}$
MAP ≥ 90 mmHg at all times in patients with isolated TBI
Sedation, if used, administered by continuous i.v. infusion
Pupillary size and reaction during transfer recorded
Written record of vital sign observations
Time from acceptance by receiving unit to departure from sending unit

Paediatric transfers are high-risk and should be jointly reviewed among the referring, receiving hospitals and the regional transport team using local governance arrangements and lessons learnt should be shared with all stakeholders.

Acknowledgements

The Working Party wishes to thank all those who have contributed to the development of this guideline. In particular, we thank Drs S. Riphagen and R. Padmanabhan of the Paediatric Intensive Care Society for their considerable assistance. No external funding or competing interests declared.

Supporting Information

Filename	Description

Filename	Description
anae14866-sup-0001-AppendixS1-S2.docx Word document, 22.7 KB	Checklist to be completed before commencing a transfer. Paediatric time-critical neurosurgical transfer checklist.

Please note: The publisher is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing content) should be directed to the corresponding author for the article.

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