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Original Research

External Ventricular Devices in Air Medical Retrievals

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A B S T R A C T

Objective: Describe the clinical characteristics of patients with an external ventricular drain (EVD) air medically retrieved.
Methods: A retrospective chart audit of adults with an EVD air medically retrieved between January 2018 and June 2022 was conducted using the Retrieval Services Queensland database. Patients with a diagnosis of subarachnoid hemorrhage were identified, and then a manual review was conducted to identify EVD cases.
Results: A total of 60 patients met the review criteria. However, 34 patients did not have an EVD in situ, 1 was not transported, and 2 charts were non-retrievable, leaving 21 patients in this review. Of the patients, 76% were mechanically ventilated and 10% had no EVD drainage (suspected to be blocked). Blood pressure fluctuations occurred in 67% of the cases (79% during flight). Separate analgesia/anesthetic infusions were administered in 75% of the patients, with 83% requiring rate increases and 100% requiring boluses for increases in blood pressure. Hypertension in 3 patients occurred post-EVD being turned off and resolved when EVD was turned back on, and bolus sedation/analgesia was provided.
Conclusion: The air medical transport of patients with an EVD is a low-frequency transfer. Therefore, the use of clinical practice guidelines will enable best practice assessment and management.

In Australia, the incidence of aneurysmal subarachnoid hemorrhage (aSAH) is between 5.3 and 6.0 cases per 100,000 person years.[1] aSAH can be complicated by hydrocephalus, requiring insertion of an external ventricular drain (EVD) to help reduce the resultant rise in intracranial pressure (ICP) until resolution or shunting. Advances in interventional neuroradiology (INR) techniques such as endovascular coiling have become common in the management of these patients.[2]

Queensland is a large state, with neurosurgical services located in Southeast Queensland (Brisbane, Gold Coast) and Townsville, North Queensland, approximately 1,351 km travel north by road or 2 to 3 hours flight from Brisbane. Before the introduction of INR in Townsville in 2021, patients with aSAH from North Queensland were managed locally with EVD and clipping, if suitable, or transferred to

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Southeast Queensland if INR was required. This created the situation of patients being transferred between neurosurgical centers with EVDs in situ and an opportunity to study this practice. Air medical retrievals, an essential part of Queensland's health care system,[3] are coordinated by Retrieval Services Queensland (RSQ), a unit of Queensland Health, with aircraft provided by the Royal Flying Doctors Service (RFDS)—Queensland Section and LifeFlight Aviation and clinical crew consisting of a medical officer and flight nurse from RFDS and/or LifeFlight Medical Services.

Clinical practice guidelines (CPGs) in health are used to describe how evidence-based standard clinical practice is applied within a given clinical service.[4] In retrieval medicine, standard CPGs also include considerations specific to the patient's exposure to the aviation environment.[5] Currently, the air medical providers in Queensland use organizational specific and independent CPGs to guide practice during the air medical retrieval of a patient with an EVD.[6,7] As there is limited research into this topic, the CPGs are based on clinical practice within the hospital system, not the retrieval environment.

This study aimed to describe the clinical characteristics of adult patients with an EVD after aSAH who required air medical retrieval, the characteristics and challenges of these transfers, and any adverse effects associated with the retrieval. Cases were reviewed against existing air medical retrieval CPGs to assess whether the documented approach is consistent and safe.

Methods

A retrospective audit of adult patients (≥18 years) with an EVD inserted for hydrocephalus after an aSAH air medically retrieved from Townsville to Brisbane between January 1, 2018, and June 31, 2022, was undertaken. It was considered likely that the only patients with EVDs being transferred would be those with aSAH requiring INR services, so subarachnoid hemorrhage was used to filter records from the RSQ Database. For the full list of search terms, see Appendix 1. Deidentified clinical records meeting inclusion were then reviewed to confirm transfer with an EVD. The data from the patient records were extracted by the principal investigator (AW), which included demographic, clinical, and transport characteristics and adverse events.

For this research project, several clinical and operation definitions were predetermined. Hypertension was defined as a systolic blood pressure (SBP) ≥ 150 mm Hg and hypotension as a SBP ≤ 100 mm Hg, capturing the risk of rebleeding with a SBP > 150 mm Hg and reduced cerebral perfusion with SBP < 100 mm Hg.[8] The length of transfer time was defined as the period from the initial patient contact at the referring hospital to handover of their care at the receiving hospital. The transport was divided into the following 4 phases: (1) ground transport: hospital to and from the airfield; (2) takeoff to cruising level (ascent); (3) cruising level; and (4) cruising to landing (descent). Patients were categorized as intubated or non-intubated.

CPGs were obtained from both air medical providers who outline the specific requirements of patients with an EVD. Guidelines described the frequency for neurological, vital signs, and EVD-specific assessment. This included level of the flow chamber, volume, color, and signs of raised ICP (decreasing Glasgow Coma Score [GCS], pupillary changes), and complications. Potential complication fields included dislodgment, excessive drainage, and lower-than-expected drainage.[6,7] Included were the recommended times that the EVD should be temporarily turned on and off such as during transfer, patient movement from the hospital bed to transport stretcher, during takeoff, and before landing and during any times of increased stimulus, such as vomiting. Additional information included specific equipment required (EVD manometer and laser level secured to a mounting pole) attached to the aircraft stretcher which has Civil Aviation Safety Authority engineering approval.

Owing to the small sample size, a univariate descriptive analysis was undertaken, and no statistical comparisons were completed.

Ethics approval for this research was granted by Townsville Hospital and Health Service Human Research Ethics Committee (HREC) (HREC/QTHS/91323).

Results

The initial database search yielded 60 charts meeting the inclusion criteria. Deidentified patient records were obtained with 36 identified as having been transferred without an EVD. The records of 2 patients were unable to be retrieved, and 1 was not transferred, leaving 21 patients included in the review.

The demographics are presented in Table 1. There was a similar distribution of males (52%) and females (48%), with a median age of 52 years. The largest number of transfers were in 2021 (n = 9) with 76% of patients mechanically ventilated. There were no altitude restrictions imposed for flight, and the cabin pressurization, where documented, was approximately 8,000 feet.

To report on the assessment and management of EVD, reference and comparison to the air medical services clinical practice guideline's (CGPs) were undertaken. During the transport, the assessment and management of EVD were variable with the frequency of documentation inconsistent. The prescribed height of the drainage chamber as ordered by the referring neurosurgeon was documented during the initial assessment in 16 cases (76%) and decreased to 3 cases (14%) during transport. The volume of cerebrospinal fluid (CSF) drainage into the flow chamber was assessed in 66% of the cases and increased to 81% during transport. In 4 cases (19%), EVD was not documented during any phase. The color of the CSF drainage was described as blood stained, rose, or serous, in 33% of the cases. Only 14% of the cases had documentation post-initial assessment about CSF appearance (Table 2).

EVD ranged from 8 mL to 120 mL; however, the hourly drainage could not be ascertained in most cases. Documentation was inconsistent and ranged from once during the transfer, to hourly, to end of transfer total and ad hoc. There was 1 case in which the hourly drainage was >25 mL/hour. In the free text of 2 cases, the EVD was described to be blocked with 0 mL drained for the entire transfer and that manual aspiration was required. There was no further documentation as to the reason for the blockage or whether the neurosurgeon was consulted before aspiration. There were no other documented dislodgement complications, with 9 cases (42%) documenting in the clinical notes when the EVD was turned off and on.

There was no documented pupillary assessment in 15% of the cases. Of the patients where pupillary assessment was recorded, 76% occurred

Table 1
Demographics of Patients Retrieved With an EVD (N = 21)

Category	Subcategory	n (%)
Total patients	Male	11 (52%)
	Female	10 (48%)
Age (y)	Median	52
	IQR	17.5
	Range	27-72
Transfers per year	2018	3 (14%)
	2019	6 (29%)
	2020	3 (14%)
	2021	9 (43%)
	2022	0%
Length of transport time (min)	Minimum	193
	Median	310
	Maximum	387
	IQR	40
Ventilation	Mechanical ventilation	16 (76%)

EVD = external ventricular drain; IQR = interquartile range.

Table 2
EVD Assessment Documentation

Prescribed Height of Flow Chamber			EVD Volume			CSF Appearance—Color		
Initial	During Transport	Handover	Initial	During Transport	Handover	Initial	During Transport	Handover
16 (76%)	3 (14%)	1 (5%)	14 (66%)	17 (81%)	8 (38%)	7 (33%)	3 (14%)	3 (14%)

CSF = cerebrospinal fluid; EVD = external ventricular drain.

Table 3
Hypotension or Hypertension During Transport

	Ventilated (n = 11)		Non-Ventilated (n = 3)		Total (N = 14)	
	Hypotension	Hypertension	Hypotension	Hypertension	Hypotension	Hypertension
Ground transport	0	1 (9%)	0	2 (67%)	0	3 (21%)
Takeoff to cruise (ascent)	2 (18%)	2 (18%)	0	0	2 (14%)	2 (14%)
Cruise	1 (9%)	2 (18%)	0	0	1 (7%)	2 (14%)
Cruise to landing (descent)	2 (18%)	1 (9%)	0	1 (33%)	2 (14%)	2 (14%)

during the initial contact. In 24% of patients, a change in size and/or reactivity was documented; however, there were no free notes to document any changes in condition. The changes were not associated with any hemodynamic changes nor the EVD being turned on or off. The documentation of pupillary assessment was inconsistent with the frequency varying between not done, hourly, and ad hoc.

Episodes of hypertension or hypotension were identified in 67% of the patients. When comparing the timing of the episodes, 79% of blood pressure variation occurred during flight as opposed to the ground transport phase (Table 3). Of the 9 patients with at least 1 documented episode of hypertension, the surrounding events were documented in the clinical notes of 3. In these 3 cases, the EVD was turned to the off position due to change in flight phase before the episode of hypertension. One of the cases was during takeoff and the other 2 episodes on descent before landing. The 1 patient who was not mechanically ventilated had a documented decrease in their GCS from 15 to 14 due to confusion. When the EVD was turned back on after the change in flight phase, the hypertension resolved and GCS returned to 15.

GCS was documented in 19 cases (90%) during the initial assessment, in all cases (100%) during the transport phase, and 8 cases (38%) at the handover. There were 3 cases with documented changes in GCS. Two of the cases, both mechanically ventilated, had a change in score from 3 to 7, though there was no description of the events surrounding the changes; this would be consistent with "waking up" from sedation. The documentation of the GCS was inconsistent with the frequency varying from not done to hourly to ad hoc.

All mechanically ventilated patients received ongoing intravenous sedation and analgesia during the transport phase. Over the study period, there was a shift from using morphine and midazolam in a combined syringe to fentanyl and propofol administered separately (Table 4). In 2018, all mechanically ventilated patients were transported using the same combined infusions that commenced at the referring hospital. From early 2019, separate infusions of fentanyl and propofol became most common but with some ongoing use of combined midazolam with morphine or fentanyl. All patients were transferred with propofol and fentanyl in separate syringes from mid-2019. During the retrieval, 25% of those with combined infusions required an increase in rate and 25% required a bolus, compared with 83% and 100%, respectively, in those with separate infusions (Table 5).

Discussion

Spontaneous aSAH is associated with up to 40% mortality,[9] with between 5.3% and 11.4% occurring in the acute period due to rebleeding from an unsecured aneurysm.[2] The risk of rebleeding is the highest within the first few days and substantially higher in patients with unsecured ruptured aneurysms. The air medical retrieval of a patient with an EVD is a very low frequency event. Despite this, the retrieval team must be familiar with management of the EVD and associated complications to ensure high-quality care.[10] This retrospective study describes the clinical characteristics of patients transported via fixed wing aircraft with an EVD in Queensland, Australia. No EVD-specific adverse events were identified; however, inconsistencies in the documentation of the assessment and management of these patients were identified. Changes in the choice and manner of sedation and analgesia administration for ventilated patients during air medical retrieval in the study period were also noted.

During the study period, CPGs specific to the transport of patient with an EVD were available and provided information on equipment requirements, the type and frequency of clinical and EVD observations, the retrieval-specific requirements, and potential complications.[6,7] The use of CPGs for this specialized patient group is supported by Hoh et al[8] who recommend the use of EVD maintenance bundles to outline best practice to reduce complications. In this study, it was not clear whether the guidelines were used due to

Table 4
Characteristics of Sedation and Analgesia Between Referring Hospital and Transport Team

	Referring Hospital Infusions	Transport Team Infusions
2018	Morphine and midazolam combined	Morphine and midazolam combined
	Fentanyl and midazolam combined	Fentanyl and midazolam combined
2019	Fentanyl and propofol separate syringes	Morphine and midazolam combined or fentanyl and midazolam combined
	Fentanyl and propofol separate syringes	Fentanyl and propofol separate syringes
2020	Fentanyl and propofol separate syringes	Fentanyl and propofol separate syringes
2021	Fentanyl and propofol separate syringes	Fentanyl and propofol separate syringes

Table 5
Sedation

Sedation for Mechanical Ventilated Patients	Separate Syringes (n = 12)	Combined Syringes (n = 4)	Total (N = 16)
Rate of infusion increased during length of transport	10 (83%)	1 (25%)	11 (93%)
No change in rate of infusion	2 (17%)	3 (75%)	5 (31%)
Bolus required during length of transport	12 (100%)	1 (25%)	81%
No bolus	0%	3 (75%)	19%

the inconsistent and variable clinical documentation or even whether the retrieval teams were aware of the existence of CPGs.

A key goal during the transport of the patient with an EVD is to ensure that rebleeding and secondary brain insults do not occur. The EVD, inserted to facilitate the drainage of CSF from the lateral ventricles,[11] is a crucial strategy for controlling ICP[12] in patients with acute hydrocephalus. In healthy individuals, CSF, which is clear, is produced at between 20 and 25 mL/hour; above this level, it is described as excessive.[10] The amount of CSF drainage is dependent on gravity, with this determined by the position (or level) of the drainage chamber, expressed in centimeters above the external reference point (tragus of the ear), reflecting the foramen of Monro.[13] Incorrect height positioning does not allow CSF to drain, increasing the risk of rising ICP. Excessive drainage may occur if the drain is too low, possibly increasing the risk of rebleeding.

To reduce the risk to misalignment of the EVD with the foramen of Monro, it is recommended that the EVD be closed before any patient movement and then opened when the patient is settled.[14] For patients who are being transported, the organization's CPGs recommend closing the EVD open drainage system during movement, takeoff (acceleration), and landing (deceleration) and to be reopened when the patient is settled.[6,7] This recommendation was not documented, and, therefore, adherence to these principles is unknown.

Assessing and identifying neurological deterioration for signs of raised ICP or rebleeding in the air medical retrieval environment can be challenging. Pupil assessment is an important assessment tool that is easily performed. Thilak et al[15] recommend, for a patient with unsecure aneurysms, the pupillary size, shape, and reactivity to light are recorded every 20 minutes once the patient is sedated and paralyzed (p.3 in Thilak et al[15]). However, Thilak et al[15] made no recommendations for patients who were not mechanically ventilated. Although this recommendation closely supports the current organizational CPGs of 15 minutely pupil assessment,[6,7] this research study found that pupillary assessment was infrequently and inconsistently recorded, noting that it may have occurred without documentation. Furthermore, although there was no documented evidence of clinical neurological deterioration in this patient group, documentation of 15 minutely pupillary assessment should remain part of CPGs.

In the non-ventilated patient, changes in GCS may reflect changes in ICP. Although the study reported that GCS assessment was performed at the initial assessment and during flight, there was no consistency in the frequency of assessment. Again, it is recommended that GCS continue to be assessed and documented every 15 minutes, to identify any neurological changes.

EVD blockages can be associated with tube kinking, migration of the catheter, and physiological factors, such as overdrainage or CSF leaks. Two patients in the study population had documented blocked EVD; however, there was no record of how this assessment was made. Although the retrieval team believed them to be blocked, it may have been due to minimal drainage. In one of the cases, the retrieval team did attempt to aspirate the drain but no further documentation on the success was recorded nor prior discussion with the coordination center or the neurosurgeon. One noninvasive strategy to assess for obstruction is to briefly lower the entire drainage system to see whether CSF flow ensued which would argue against a fixed obstruction.[16] There was no evidence in the clinical documentation that this troubleshooting strategy was used.

In adult intensive care units (ICUs), there has been a shift from deep to lighter sedation in the mechanically ventilated patient, resulting in decreased hospital mortality and length of ICU admissions.[17] In the course of our study period, we identified a change from combination analgesia (morphine or fentanyl) and midazolam (long-acting sedative) infusions to separated infusions of fentanyl (analgesia) and propofol (short-acting sedative). Propofol, a common sedative in neurointensive care units used for its short duration of action, allows a patient to be woken frequently and on short notice for neurological examination,[18] whereas the use of midazolam, a longer acting sedative, has been associated with longer mechanical ventilation times.[19]

The change to separated infusions of analgesia and short-acting sedatives overall demonstrated a trend toward an increase in hypertensive episodes, which required boluses and increases in rate of administration. Subsequently, there were episodes of rebound hypotension and the requirement for short-term vasopressors. Although not identified in this study, fluctuations in blood pressure variability may be associated with rebleeding.[20] The prevention of hypotension and adequate analgesia and sedation are management strategies for the control of ICP.[15] The use of short-acting sedatives may be appropriate within the ICU; however, in the retrieval environment, patients are exposed to a high level of stimulation, such as aircraft noise, vibration, the effects of acceleration and deceleration, and frequent physical transfers, that is, from hospital bed to stretcher and vice versa. Deeper short-acting sedation during air medical retrieval may provide more hemodynamic stability, especially for the patient with an unsecured aneurysm. This is supported by Sorteberg et al[21] who found that, during inter/intrahospital transport, there was a relationship between rebleeds and transport and recommended adequate sedation and analgesia to minimize stress and discomfort.

The air medical retrieval system in Queensland comprises a centrally coordinated statewide system and contracted retrieval services. With a statewide focus, there is a need for definitions and accurate real-time data collection that are consistent across all service providers. Current challenges include real-time access to in-flight patient records, with multiple health professionals from different retrieval services relying on the same clinical records for a single patient tasking. Ideally, a statewide system linking all air medical retrieval services, including air medical equipment and aviation flight details such as altitude reached and changes, would be beneficial. Such an integrated system would enhance understanding of the impact of air medical transport on patient well-being.

Limitations

A limitation of this retrospective study was the quantity and quality of data available from the clinical records. The documentation was recorded by 2 air medical services, with a combination of paper based and electronic records. There were ongoing discrepancies between timing and clinical information. It was anticipated that any adverse events would be captured as free text within the clinical records. In researching for adverse events, this project focused on the air medical retrieval with access to clinical records after clinical handover to the receiving facilities, not available. As there was a small number of patients, with missing and incomplete data, it was underpowered to identify any statistical differences between aspects of the patients' care.

Conclusion

In the air medical system where CPGs are available, immediate complications during transport of patients with an EVD are low, despite the infrequent yet high-risk nature of the transfers. Adherence to the use and regular reviews of the CPGs may further enhance safety. Further research into sedation and analgesia protocols for the EVD patient cohort is needed to minimize hemodynamic instability, support vigilant assessment, and improve clinical documentation, ultimately optimizing safety and patient outcomes.

Declaration of competing interest

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CRediT authorship contribution statement

Anita Wall: Conceptualization, Data curation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Clinton Gibbs:** Methodology, Supervision, Writing – review & editing. **Lachlan Quick:** Writing – review & editing. **Jan Sadewasser:** Writing – review & editing. **Katie Clift:** Writing – review & editing. **Richard C. Franklin:** Methodology, Formal analysis, Supervision, Writing – review & editing.

Appendix 1. Search Term

"Diseases of the Circulatory System" inclusive of "subarachnoid haemorrhage," "subarachnoid haemorrhage-atraumatic," "intracerebral haemorrhage," "intracerebral haemorrhage-atraumatic," "non-traumatic intracerebral haemorrhage," "other non-traumatic intracranial haemorrhage," "cerebral aneurysm non ruptured," "aneurysm-other," and "aneurysm of unspecified site."

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