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External Ventricular Drains After Subarachnoid Hemorrhage: Is Less More?

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Abstract

External ventricular drains (EVD) are essential in the early management of hydrocephalus and elevated intracranial pressure after subarachnoid hemorrhage. Once in place, management of the EVD is thought to influence long term patient outcomes, rates of ventriculitis, incidence of delayed cerebral ischemia after subarachnoid hemorrhage, need for a ventriculoperitoneal shunt, and ICU and hospital length of stay. The available evidence supports adopting early clamp trials and intermittent CSF drainage. However, a recent survey demonstrated that most neurological ICUs employ the opposite approach of continuously open EVDs and gradual weaning. In this article, we review the literature and arguments for and against the different EVD approaches. We conclude that an early clamp trial and intermittent CSF drainage can be safe and result in fewer EVD complications and shorter length of stay. Given the discrepancy between the available evidence and current practice, more studies on the optimal management of EVDs are warranted with the greatest need for multicenter prospective studies.

Search terms

subarachnoid hemorrhage; hydrocephalus; vasospasm; postoperative complications; length of stay

Introduction

Placement of an external ventricular drain (EVD) is a key procedure in the emergent management of hydrocephalus and elevated intracranial pressure (ICP) after subarachnoid hemorrhage (SAH). The management of the EVD once in place, however, is not always clear. Should it be left continuously open or open only when there is a high ICP? When is the best time to take it out? How do you go about taking it out? Does it make any difference? The answers to these questions are controversial and have yet to be settled¹. But the management is important because of the potential impact on the incidence of EVD complications, rate of VPS placement, treatment of delayed cerebral ischemia, and ICU and

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hospital length of stay². Comprehensive reviews on the management of EVDs^{2,3} and SAH^{4,5} are individually covered elsewhere. Since the indications for placement of an EVD after SAH are generally well-accepted and standardized²⁻⁵, in this review we will focus specifically on the challenge of how to manage an EVD once placed.

Materials and Methods

We performed a comprehensive literature search of PubMed, Embase, and Cochrane review databases from 1960 to July 2017. We only included prospective studies which compared rapid vs. gradual weaning or intermittent vs. continuous CSF drainage.

Results

A PubMed search using keywords “external ventricular drain subarachnoid hemorrhage” returned 258 results. An Embase search using the same keywords returned 214 results. A search of PubMed using the MeSH terms “Subarachnoid Hemorrhage” and “Drainage” returned 169 results. Finally, a search of the Cochrane Database of Systematic Reviews using the keywords “subarachnoid hemorrhage” returned 14 results. Of all the results we found 4 papers (Klopfenstein 2004⁶, Amato 2011⁷, Kim 2011⁸, and Olson 2013⁹) which met our criteria of prospective studies comparing rapid vs. gradual EVD weaning or intermittent vs. continuous CSF drainage (Table). All 4 papers report single center prospective studies of patients with subarachnoid hemorrhage. Klopfenstein et al.⁶ reports a single center randomized controlled trial (RCT) of rapid vs. gradual EVD weaning. Olson et al.⁹ reports a single center RCT comparing intermittent vs. continuous CSF drainage. Amato et al.⁷ and Kim et al.⁸ report on the same cohort of patients from a single center observational study. Therefore, these 4 papers represent 3 distinct prospective studies of EVD management after SAH.

The only randomized controlled trial (RCT) of rapid vs. gradual EVD weaning is a single center study from the Barrow Institute in 81 patients, which demonstrated that EVD, ICU, and hospital days were reduced by a rapid EVD wean strategy⁶. There was no difference in the incidence of VPS placement. However, the major weakness of this study was that the investigators tolerated only 1 wean failure prior to placing a VPS which was done out of the belief that getting patients to a rehabilitation center earlier would improve their long term functional outcomes¹⁰. This resulted in high VPS rates of >60% in both the early clamp trial and gradual wean groups. Additional author-noted criticisms were that the gradual wean period of 96 hours was arbitrary, the timing of wean was determined subjectively, and the study was not powered to detect subgroups that might benefit from a gradual wean.

There are 2 papers that report on a single prospective observational study comparing continuous vs. intermittent CSF drainage. The papers are complementary and focused on respective and nursing⁷ and medical⁸ outcomes. Neither reported a significant difference in the rate of symptomatic vasospasm. However, there was a non-significant trend towards lower VPS placement rate and fewer EVD-related complications in the intermittent CSF drainage group. These studies provided the motivation behind a subsequent RCT.

Olson et al. performed the only RCT comparing a continuous vs. intermittent drainage strategy in 60 SAH patients at the same institution as the above observational study⁹. The question asked in this study is different from the Barrow RCT because an intermittent drainage strategy (i.e. closing the drain whenever possible) does not rely on a subjective determination of wean. Rather, intermittent drainage is effectively an early clamp trial performed repeatedly. The most notable finding from the study by Olson et al. is that an intermittent drainage strategy results in fewer EVD complications. Indeed, the trial was terminated early by the clinical safety committee due to an unacceptably high rate of EVD malfunction (non-patency) and ventriculostomy-related infection in the continuously open group. There was no difference between the groups in the primary outcome of symptomatic vasospasm. In addition to being stopped early, the study was limited in that it only included one center. Furthermore, the study may not have reflected EVD maintenance practices at other centers as the rate of ventriculitis in both arms were high.

Discussion

We found that there are very few prospectively collected data that attempt to assess the optimal approach to discontinue an EVD. Our results are consistent with a recent comprehensive review of the literature commissioned by the Neurocritical Care Society² which highlighted the Barrow RCT of rapid vs. gradual weaning⁶. We found an additional 3 papers⁷⁻⁹ which prospectively determined the effect of an intermittent vs. continuous CSF drainage approach.

The Rapid vs. Gradual Wean Approach

A rapid wean is when the EVD is immediately closed once the decision is made to try discontinuing the EVD. This contrasts with a gradual wean, which typically involves leaving the drain open for a prolonged period, followed by a period of weaning, during which the drain is raised gradually (e.g. from 10 to 15, then 15 to 20, then 20 to 25 cm H₂O) over several days until it is eventually clamped and discontinued. It is unclear if one method is truly preferable over the other.

One argument for a rapid wean is that it can more safely and readily detect symptomatic hydrocephalus. Using modern ICU monitoring, once the EVD is closed, ICP is continuously transduced, and an alarm is set for high ICP. Many neurosurgeons and neurointensivists have been taught that it is risky to clamp an EVD during the vasospasm period, but again if the main concern is cerebral perfusion pressure, this can be monitored during a clamp trial, and the system reopened if cerebral perfusion pressure is compromised. An even more compelling argument given for a rapid wean is the potential for a higher probability of successful removal of the drain, as well as earlier removal of the EVD. Theoretically, a rapid wean may lead to increased recruitment and utilization of clogged CSF resorption pathways in the arachnoid granulations. Earlier removal of the EVD may also reduce the risk of ventriculostomy-related infection and reduce ICU length of stay.

The Barrow RCT suggests that rapid weans can reduce EVD, ICU, and hospital days, with no adverse effects on safety, the frequency of delayed cerebral ischemia (DCI), or clinical outcome.⁶ Of note, the rate of VPS placement was greater than 60% in both groups, which is

higher than the more typical 40% reported in other large series.^{11,12} Regardless, a recent survey of neurocritical care units in the United States found that three times as many centers use a gradual over a rapid wean.¹³ Hence, it is clear that the community has not adopted the results of the Barrow study. Therefore, the question of rapid vs. gradual wean is far from settled and will require further study.

The Continuous vs. Intermittent Drainage Approach

Another fundamental management variable is the question of continuous vs. intermittent EVD drainage. In effect, intermittent drainage is early and repeated application of a rapid wean since only a clamped drain can be intermittently drained. Continuous drainage requires not only that the drain be left open but that additional decisions be made about when and how to wean the EVD. Therefore, the rapid vs. gradual and continuous vs. intermittent dichotomies are related but distinct management questions.

There is general agreement about how to manage an EVD after aneurysm rupture and prior to clipping or coiling. Almost all institutions adopt the strategy of minimizing CSF drainage by keeping the drain either closed or open at a relatively high level¹³. This is out of fear that a pressure gradient formed by a wide open drain would increase the chance for re-rupture based on historical data suggesting that re-rupture was associated with relatively low ICP¹⁴. Frequently, there is no choice but to keep the drain open when there is symptomatic hydrocephalus, ICP is unacceptably high, or the drain must be opened too many times for it to be practical to use an intermittent drainage strategy. Minimizing CSF drainage by default when the aneurysm is still unsecured appears to be a sound strategy.

Choosing between a continuously open vs. intermittently open drainage approach is less clear once the aneurysm is secured. There are multiple reasons given to use a continuously open drainage approach: (1) the patient needs the EVD open for symptomatic hydrocephalus, (2) to clear blood, (3) to reduce the risk of shunt occlusion, and (4) to improve cerebral perfusion pressure. The primary reason to place and maintain the EVD is for symptomatic hydrocephalus. There is no question that if the ICP is also high that the EVD should be left open and continuously draining. But what if the exam and ICP have improved and the patient only needs the drain opened once every 2 hours to keep ICPs under control? What if the ICP is normal and the patient is stable? How do we decide whether to take an intermittent or continuous drainage approach?

Proponents of the continuous EVD drainage approach point to the idea that clearing blood products in patients with aneurysmal subarachnoid hemorrhage can prevent cerebral vasospasm and delayed infarcts regardless of the presence of hydrocephalus or elevated ICP. The rationale is that blood in the subarachnoid space causes inflammation which leads to vasospasm and neurological worsening. This drives the practice of washing out blood in the subarachnoid space during the craniotomy for aneurysm clipping. The belief that retained blood products lead to worse neurological outcomes has also led practitioners to place *cisternal* drains for the primary purpose of clearing blood products¹⁵. Other centers routinely use spinal drains or serial large volume lumbar puncture in patients with SAH for the same purpose^{16–18}. If the goal is to clear blood products from the subarachnoid space, removal of CSF through cisternal or spinal drainage might be more rational approaches than an

upstream modality such as an EVD. There simply are not enough high quality studies to suggest that EVDs effectively clear subarachnoid blood and reduce the rate of delayed cerebral ischemia^{4,5}.

Another reason why some practitioners aim to keep the EVD continuously open is to minimize ICP and by extension maximize cerebral perfusion pressure. For elevated ICPs, an EVD is necessary to control and monitor ICPs and in SAH there is compelling evidence of an optimal cerebral perfusion pressure¹⁹. Furthermore, practitioners may be extrapolating a 2016 Brain Trauma Foundation Level III recommendation stating that “an EVD system zeroed at the midbrain with continuous drainage of CSF may be considered to lower ICP burden more effectively than intermittent use.”²⁰ But for an ICP of 15 mm Hg, for example, the advantage of increasing cerebral perfusion pressure via further lowering of ICP as opposed to simply increasing systemic blood pressure is not clear.

What about the rationale behind an early clamp, intermittent drainage strategy? The best available evidence comes from the Olsen RCT which found that a closed drain with intermittent CSF drainage is associated with lower rates of EVD malfunction.⁹ Despite the limitations of the study (discussed in Results), the trial remains the strongest evidence to date that an intermittent drainage strategy is as safe as a continuously open strategy and may result in fewer EVD complications.

There is an additional theoretical reason for how an intermittent drainage strategy might save ICU and hospital days, particularly for low grade SAH and ICH patients. It has been proposed that closing the drain allows arachnoid granulations to take over their role, and that earlier and higher pressures better promote granulation reactivation, reducing the need for lifetime VPS placement. This hypothesis represents an opportunity for pre-clinical and ICU-based research. Regardless of the rationale behind an intermittent drainage approach, the main downside is the frequency with which the EVD must be reopened for elevated ICP. It seems reasonable that if the EVD system needs to be reopened twice within an hour, it should remain open continuously.

Therefore, an early clamp, intermittent drainage strategy for EVD management after SAH or ICH appears to be safe, potentially results in fewer complications, and leads to an effective rapid wean without evidence of worse patient outcomes. However, almost no centers practice early clamping and intermittent drainage¹³. It appears that the practice of the neurocritical care and neurosurgical communities were not moved by the increased number of EVD complications in continuously drained EVDs from the randomized controlled study by Olson et al.⁹ Often we repeat the teachings of what we have been taught. There is no doubt that further study is warranted.

Discrepancy Between Evidence and Practice

We are not sure why there is a discrepancy between the best available evidence and current practice. The primary reason must be that the best evidence that we have is limited. There is only one single center RCT supporting rapid over gradual weaning⁶ and one single center RCT supporting an early clamp intermittent over continuous EVD drainage⁹. The threshold of evidence to overcome historical practice is likely simply not met.

Additionally, we have encountered practitioners who prefer to maintain an EVD in asymptomatic patients just in case they develop radiographic or symptomatic vasospasm. Therefore, even for low grade patients without hydrocephalus there is a reluctance to discontinue the EVD as long as the patient is within the vasospasm window. Historically, there used to be a rationale for maintaining EVDs even in a low grade patient without hydrocephalus. This is because intra-arterial papaverine causes a significant rise in ICP during rescue treatment for vasospasm²¹. There is no question that when papaverine was used for treatment of vasospasm that it was necessary to have an EVD in place. However, with the current use of intra-arterial calcium channel blockers and milrinone (which do not cause significant rises in ICP) rather than papaverine, this rationale has disappeared. A related reason that some practitioners give for maintaining an EVD is that if vasospasm and delayed cerebral ischemia develops, then the EVD can be opened and dropped to a low level to improve cerebral perfusion pressure while awaiting intervention. As mentioned above, for patients with secured aneurysms and normal ICP, the same physiologic effect on perfusion pressure can be achieved by enhancing MAP. Therefore, we find no compelling reasons having to do with rescue therapy or vasospasm to maintain an EVD in a patient without hydrocephalus. Finally, prolonged EVD placement can at times reflect a different management style between neurosurgical and neurocritical care treating teams.

Conclusions

There are arguments for both closing or opening the drain, and for rapid versus gradual weans. Our opinion is that the argument for an early clamp and intermittent drainage strategy, when possible, is most compelling given the available evidence, particularly for low-grade patients who are least likely to need long term CSF diversion. Additionally, an early clamp and intermittent drainage strategy is simpler and requires less effort to maintain when tolerated. Staff can then focus on other pressing aspects of ICU care. In the end, however, the neurocritical care and neurosurgical communities have not adopted the practice suggested by the current level of evidence which is that early clamping coupled with an intermittent drainage strategy is safe, results in fewer complications, and leads to shorter length of stay¹³. We need to prioritize high quality multicenter prospective studies that revisit this topic to reach a threshold of evidence to effect a practice change.

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Table

Prospective studies of rapid vs. gradual weaning and intermittent vs. continuous CSF drainage of EVDs after SAH.

Ref	Design	N	Comparison	Outcomes	Findings
Klopfenstein 2004 ⁶	RCT	81	Rapid vs. gradual	VPS, LOS	Gradual had longer ICU and hospital LOS
Amato 2011 ⁷	Observational	37	Intermittent vs. continuous	VSP, EVD complications	No difference
Kim 2011 ⁸	Observational	37	Intermittent vs. continuous	VSP, EVD complications	No difference
Olson 2013 ⁹	RCT	60	Intermittent vs. continuous	VSP, EVD complications	Continuous had more EVD complications

RCT: Randomized controlled trial, VSP: symptomatic vasospasm, VPS: ventriculoperitoneal shunt placement, LOS: length of stay