Epidural blood patch: A study on an experimental model

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ABSTRACT

Aim: Epidural blood patch has been used to treat spinal headache with varying success. An experimental model was designed to ascertain whether an epidural blood patch can be used to seal the needle puncture sites in dural repair. **Materials and Methods:** Bovine dura was secured to the lower end of an open-ended calibrated plastic cylinder. Multiple interrupted stitches were applied over a 02 cm length of the dura without any incision. The cylinder was filled with colored saline gradually with the dura placed in a dependent position. Height of the water column at which sutured dura leaked was recorded. A layer of fresh blood was laid over the dura and allowed to clot. The test was repeated and the hydrostatic pressure at which leak took place was noted again. The test was repeated three times. Similar studies were done with two specimens with 02-cm dural incisions repaired with interrupted stitches of 4-0 silk in one specimen and 4-0 prolene in another, and three specimens with 3-mm unsutured dural rent in one and dural punctures made with 23-G and 26-G spinal needles in the other two. **Results:** All the dural preparations leaked, at a very low hydrostatic pressure (<30 mm of H_2O). By covering the needle puncture sites with clotted blood, a watertight closure could be achieved, that can withstand a much higher hydrostatic pressure (mean of 180 mm of H_2O). **Conclusion**: The experimental findings indicate that an epidural blood patch does enhance the ability of a dural closure to prevent a leak; however, its utility in clinical setting is questionable.

Key words: Epidural blood patch, experimental model, water-tight dural closure

INTRODUCTION

Achieving a watertight dural closure is considered fundamental to a successful supratentorial neurosurgical procedure. Controversies exist claiming superiority of one closure technique over another. However, clinical experience has suggested and experimental studies have proven[1,2] that a watertight dural closure is impossible to achieve with any suturing technique, since CSF leak takes place through the needle puncture sites. In experimental models, cyanoacrylate glue has proven effective in closing the needle puncture sites;[1] however, only limited number of studies are available confirming its safety and efficacy in clinical settings. Fibrin glue has been used to prevent CSF leak in different settings, but its use is limited in routine practice due the cost of the material, technical difficulty in applying it properly and yet unanswered queries about the concern regarding the effect of fibrin glue on bone formation.[3] The epidural blood patch has been used as a treatment of post spinal headache, with an understanding that it blocks the dural rent and may also contribute to the dural healing.[4]

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An experimental model was designed to ascertain whether an epidural blood patch can be used to seal the needle puncture sites in dural repair, thereby securing a truly "water-tight" dural closure. Experiments were also intended to quantify the extent of "watertightness" rendered to the dura by defining the maximum hydrostatic pressure to which the sutureline could resist any leak. Experiments were also done to document its usefulness in other settings.

MATERIALS AND METHODS

Bovine dura was collected from abattoir and transported in normal saline. It was used for the study within 4 hours of animal slaughter. Dura was secured to the 4 cm diameter, lower end of an open-ended calibrated plastic cylinder. To ensure that the model was watertight, dura was first secured with a silk thread tied around it and then all the edges of the dura were sealed to the plastic cylinder using cyanoacrylate. Each time, before commencing the tests, intactness of the model was tested against a hydrostatic

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pressure of 230 mm of H_2O. Bottles were placed, with the dura in the dependent position, over a piece of blotting paper kept over a glass slab [Figure 1a]. Any leak was noted by an observer looking at the blotting paper from underneath, as indicated by spotting over the blotting paper [Figure 1c]. At this point, level of the saline in the bottle was noted, with the height of the water column indicating the hydrostatic pressure over the suture line, by a second observer.

Following preparations were made

(i) Three specimens (Specimens 1 to 3) were prepared with the dura stretched tightly across the open end of the cylinders. Multiple interrupted silk stitches with 4-0 silk on a round body needle was applied over an unincised 2 cm length of the dura, with 2 mm bites placed at a 2 mm distance from each other with a tension, as would be considered appropriate in routine neurosurgical practice to close a durotomy [Figure 2d].

(ii) Five more dural specimens were prepared in following different ways:

(a) multiple interrupted stitches with 4-0 silk on a round body needle was applied to close a linear incision made over a 02 cm length over a lax dura (specimen 4, Figure 2e).

(b) Multiple interrupted stitches with 4-0 prolene on a round body needle was applied to close a linear incision made over a 02 cm length of lax dura (specimen 5, Figure 2f).

(c) On a lax dura a 3 mm incision was made and left unsutured (specimen 6, Figure 2a).

(d) On a lax dura a needle puncture was made with a 26-G spinal needle (specimen 7, Figure 2b).

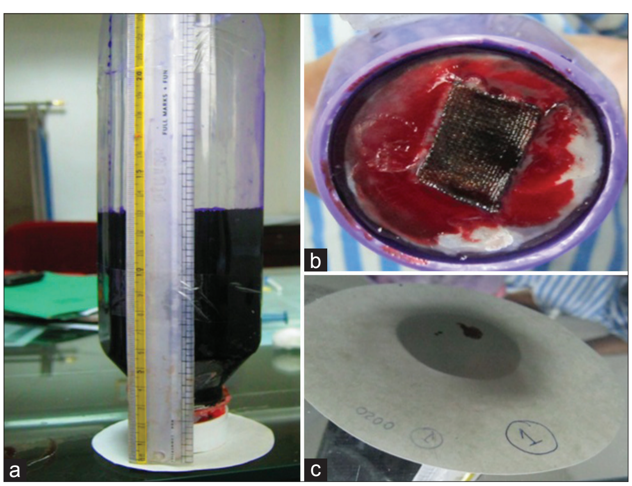

Figure 1: (a) Experimental model was kept on a glass slab over the edge of a table, on a blotting paper, and observed from under the slab for a leak, while filling up from the top with colored saline. (b) Suture/puncture site covered with a blood-soaked piece of knitted oxidized cellulose. (c) Leak in the suture line as evidenced by spotting in the blotting paper as seen by an observer looking at the blotting paper from underneath the glass slab

(e) On a lax dura a needle puncture was made with a 23-G spinal needle (specimen 8, Figure 2c).

After testing all the dural preparations for their ability to resist leak when in the dependent position, and recording the hydrostatic pressure at which they failed, following preparations were made.

On all the specimens, oxidized cellulose was placed over the suture line and fresh blood was dropped over it to form a clot, large enough to close the suture line and the needle puncture sites [Figure 1b].

The calibrated plastic cylinders were now placed with the dural end facing downward, on blotting papers. By the method detailed above, all the preparations were tested for their ability to resist water leak against increasing hydrostatic pressure, as colored saline was poured gently from the top.

RESULTS

With the needle puncture sites un-occluded, all the specimens leaked at a very low hydrostatic pressure. Only three specimens could resist a hydrostatic pressure of more than 30 mm of H_2O. They were specimens 4, 5, and 8, i.e., those with lax dura sutured with interrupted silk stitches (64 mm of H_2O), lax dura sutured with interrupted prolene stitches (54 mm of H_2O) and the one with a needle puncture made with a 26-G spinal needle over a lax dura (32 mm of H_2O), respectively. With the design limitations of this model, it was not possible to

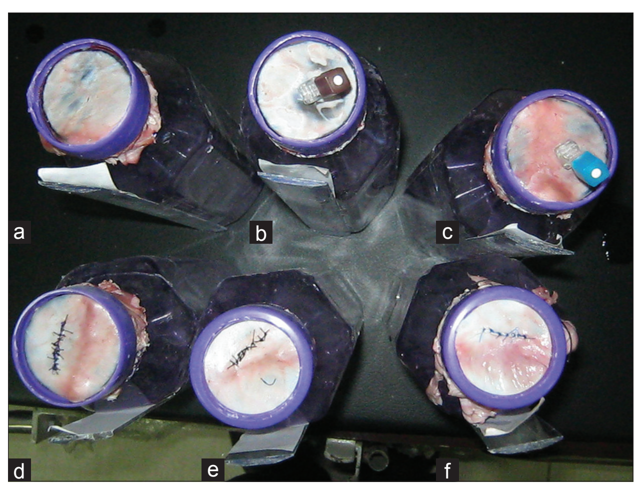

Figure 2: (a) A 3-mm unsutured incision over lax dura. (b) Needle puncture made with a 26-G spinal needle. (c) Needle puncture made with a 23-G spinal needle. (d) A 2-cm linear marking over intact dura, with interrupted stitches of 4-0 silk on a round body needle taking 2 mm bites at a 1-2 mm distance from each other over the length of the marking. (e) A 2 cm linear incision over lax dura sutured with Interrupted stitches of 4-0 silk on a round body needle (f) A 2 cm linear incision over lax dura sutured with Interrupted stitches of 4-0 prolene

accurately measure the column height when it was less than 30 mm.

When the tests were repeated with the blood clot covering the dural puncture sites [Table 1], the results varied widely with a minimum of 150 mm of H_2O pressure tolerated by 23-G needle puncture site (S7) and a maximum of 230 mm of H_2O resisted successfully by an unsutured 3 mm incision made over a lax dura covered by epidural blood patch (S6). Those three specimens with interrupted stitches over 02 cm length of tense intact dura (S1-S3) showed considerable variation (S1-215, S2-152, S3-174 mm of H_2O) in their ability to resist leak.

The specimen (S6) which resisted leak till 230 mm of H_2O, when left in this position, started leaking after 16 minutes.

DISCUSSION

The watertight closure of the dura mater is considered fundamental to intracranial procedures in neurosurgery. Every possible effort is made by the neurosurgeon to ensure the same. Different suture techniques and suturing materials have been claimed to have superiority over others in achieving the goal. CSF leak, however, continues to be one of the leading and dreaded complications in neurosurgical practice. *In vitro* studies[1,2] and experiments on animals[5] have been done to determine the best closure technique. Recent *in vitro* study[1] indicated that "(i) in a properly sutured dural incision, leaks occur primarily from the needle pores, and (ii) in the dependent position, dural closure by any technique is likely to leak". For last many years, autologous epidural blood patch has been used to treat post spinal headache.[4] The mechanism of its action is postulated to be sealing of the dural tear by blood clot. Blood clot is also considered to play a role in dural healing.[6]

Table 1: Test results

Dural specimen	Hydrostatic pressure at saline leak (mm of H_2O)		
	Unoccluded	Covered with epidural blood clot	Remarks
Interrupted stitches over 02 cm length of tense intact dura (S1-S3)	<30*	S1-215 S2-152 S3-174	Mean 180.33
Interrupted silk 4-0 stitches on a 02 cm incision line over lax dura (S4)	64	226	
Interrupted prolene 4-0 stitches on a 02 cm incision line over lax dura (S5)	54	203	
Unsutured 3-mm dural rent over lax dura (S6)	<30*	230	Started leaking after 16 min
23-G Spinal needle puncutre site (S7)	<30*	150	
26-G Spinal needle puncutre site (S8)	32	182	

* Due to the design limitations of this model, it was not possible to accurately measure the column height when it was less than 30 mm.

The aim of this study was to determine if we can use the same autologous epidural blood patch to our advantage in neurosurgery. Concerns regarding the possibility of the blood patch acting as a nidus for infection can be partially alleviated by the safety reports of the epidural blood patches used for spinal headache.[4]

In this study, all the dural specimens with unoccluded needle pores leaked at a very low hydrostatic pressure (<65 mm of water), much below the normal range of CSF pressure (50 to 100 mm of H_2O). The specimen with interrupted silk sutures applied over a 2-cm incision over a lax dura performing the best (leaked at 64 mm of H_2O), followed by the one with prolene stitches applied in similar conditions. The leakiness was understandably less for a needle puncture made with a 26-G spinal needle (leaked at 32 mm of H_2O) as compared to that with a 23-G spinal needle (leaked at <30 mm of H_2O). This was similar to the findings in our earlier study.[1] In the *in vitro* study conducted by Megyesi *et al.*,[2] the minimum pressure at which the suture lines leaked was much higher (170 mm of H_2O). These discrepancies can be explained by the fact that unlike in our study, the dural suture line was placed on the superior most part of the model.

In the second part of the present study, when the needle puncture sites were closed with blood patch, all the specimens showed an enhanced ability to resist leak. The results varied widely with a minimum of 150 mm of H_2O pressure tolerated by 23-G needle puncture site (S7) and a maximum of 230 mm of H_2O resisted successfully by an unsutured 3 mm incision made over a lax dura covered by epidural blood patch (S6). The values in the same category, i.e. those three specimens with interrupted stitches over 02 cm length of tense intact dura (S1-S3), showed considerable variation (S1-215, S2-152, S3-174 mm of H_2O).

The specimen which resisted leak till 230 mm of H_2O, when left in this position, started leaking after 16 min, suggesting that a constant pressure can stretch the dural defects leading to a breach even after they have been sealed by a blood clot.

The normal intracranial pressure varies from 50 to 150 mm of H_2O. During 'Plateau' waves, described by Lundberg as 'A' waves, pressure waves above 1000 mm of H_2O are recorded, which can be expected to happen frequently in clinical settings, exposing the dural sutureline to hydrostatic pressures much above what the epidural blood patches have shown themselves to be capable of resisting in these experiments. Hence, an ability to resist leak to a hydrostatic pressure of 180 mm of Hg may not be of any practical utility.

CONCLUSION

The experimental findings indicate that an epidural blood patch does enhance the ability of a dural closure to prevent a leak, when in dependent position, at least till 149 mm of H_2O. With a normal intracranial pressure of 50-150 mm of H_2O, reaching above 1000 mm of H_2O during 'Plateau' waves, utility of epidural blood patch to prevent CSF leak in clinical setting is questionable.

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