

Watertight dural closure! An *in vitro* study to explore the myth

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ABSTRACT

Aim: The watertight closure of the dura mater is fundamental to intracranial supratentorial procedures in neurosurgery. Controversies exist claiming the superiority of one closure technique over another. But is 'Water-tight' dural closure really achievable? An *in vitro* study system was developed to test the pressures at which dural incisions, closed with sutures, leaked. **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 two 2 cm length of the dura without any incision. Similarly a 2 cm incision was made and closed with interrupted and continuous stitches. Cylinder was filled with colored saline gradually. Height of the water column at which sutured dura leaked was recorded. The tests were conducted with the dura both in lax and tense conditions. Inlay closure technique was also tested on the same model using a dural substitute. **Results:** Even without an incision, needle puncture sites over a dura, leak, at a very low hydrostatic pressure ($30 < \text{mm of H}_2\text{O}$), though a continuous interlocking suture performs slightly better than an interrupted suture technique. If the needle puncture sites are closed with glue, both the suture techniques can achieve a watertight closure against a hydrostatic pressure of 240 mm of H₂O. **Conclusion:** In the experimental model described, 'Water-tight' dural closure appears to be impossible with suture closure of a dural defect.

Key words: Dependent position, experimental model, watertight dural closure

INTRODUCTION

While the traditional wisdom says that a watertight dural closure is fundamental to a successful supratentorial neurosurgical procedure, there is no standardized procedure to secure the same. Controversies exist claiming the superiority of one closure technique over another. But is 'water-tight' dural closure really achievable? An *in vitro* study system was developed to test the pressures at which dural incisions, closed with sutures, leaked. Tests were conducted on a linear incision closed with interrupted and continuous interlocking silk stitches. The tests were conducted with the dura, both in lax and tense conditions. In-lay closure technique was also tested on the same model using a dural substitute.

MATERIALS AND METHODS

Bovine dura was collected and transported in normal

saline. It was used for the study within 3 h of animal slaughter. Dura was secured to the 4 cm diameter, lower end of an open-ended calibrated plastic cylinder [Figure 1]. 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 fixed to the plastic cylinder using cyanoacrylate. Each time intactness of the system was tested against a hydrostatic pressure of 240 mm of H₂O, before commencing the experiment.

Different suture techniques were tested on different pieces of dura mounted over the plastic container as described. Water tightness of each preparation in dependent position was confirmed by inverting the bottle and filling it up gradually with coloured saline, prior to subjecting them to incision/suturing. Bottles were placed over a piece of blotting paper over a glass slab and from below any leak was noted by an observer, as indicated by spotting over the blotting paper. 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 [Figure 1].

Following preparations were made with dura under tense and lax conditions [Figure 2]:

- (i) Multiple interrupted silk stitches with 4-0 silk on a round body needle were applied over an unincised 02 cm length of the dura

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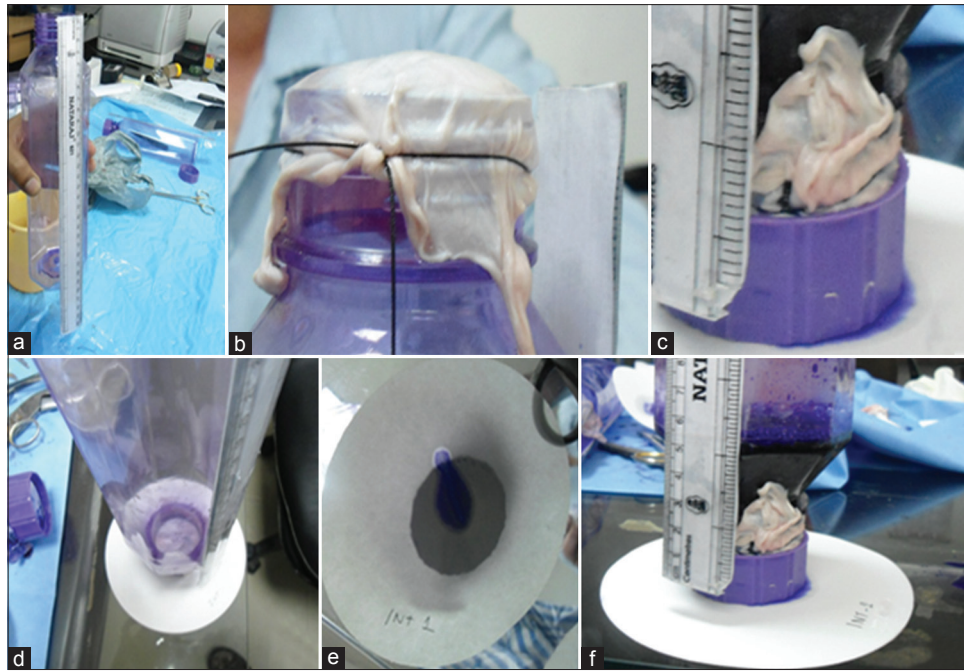


Figure 1: (a) An open-ended, cylindrical, calibrated, plastic container; (b) Dura secured with a silk thread to the 4 cm diameter opening of the container; (c) Margins of the dura pasted with cyanoacrylate glue to the outer surface of the containers; (d) Experimental model kept on a glass slab over the edge of a table, over a blotting paper, and observed from below; (e) Saline leak could be detected by noticing any spotting over blotting paper and (f) Height of the saline column was noted at the point if leaked

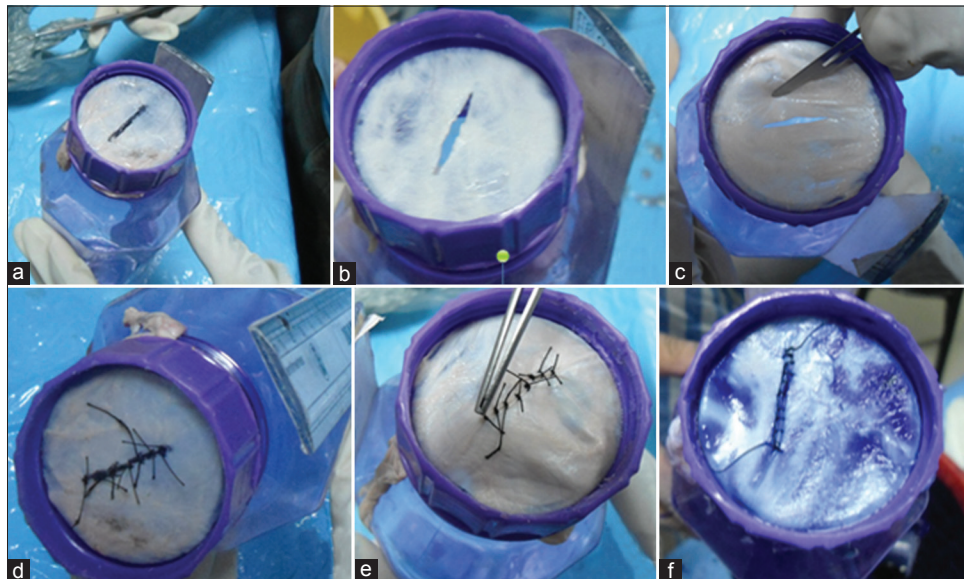


Figure 2: (a) 2 cm linear marking over intact dura; (b) 2 cm linear incision over tense dura; (c) 2 cm linear incision over lax dura; (d) interrupted stitches over 2 cm length of intact dura; (e) interrupted silk suture closure of a 2 cm linear incision over lax dura and (f) continuous interlocking suture closure of a 2 cm linear incision over a lax dura

- (ii) Multiple interrupted silk stitches with 4-0 silk on a round body needle were applied to close a linear incision made over a 02 cm length over the dura
- (iii) A linear incision made over a 02 cm length over the dura was closed with continuous interlocking 4-0 silk thread on a round body needle.

Interrupted sutures were placed three to four sutures per centimeter, using 1 to 2 mm bites (i.e., 1-2 mm of

dura incorporated into each bite on either side of the closure).

Running sutures were placed with three to four throws per centimeter, using 1to 2 mm bites on either side of the closure. The degree of tension on the lagging strand when a running stitch was used was kept as constant as possible at a tension level compatible with that routinely used in neurosurgical procedures.

After repeating the tests thrice with the interrupted and continuous suture techniques, tests were repeated once, after closing the needle puncture sites by applying cyanoacrylate glue over all three models (those specimens showing maximum ability to resist leak, in each category, were chosen).

In-lay closure technique was also tested on the same model using a nonpermeable, stretchable dural substitute (rubber sheet). This was done by securing a piece of the rubber sheet to the 4 cm diameter, lower end of an open-ended calibrated plastic cylinder. A 02 cm diameter circular opening was made in the center of the rubber sheet. Another circular piece of rubber sheet was placed over the inner aspect of the dural substitute to cover the defect with a 02 cm overlap over the margins all around and the test was repeated.

RESULTS

Test results with the needle puncture sites un-occluded [Table 1].

The dural specimens, in which sutures were applied over un incised dura, leaked in dependent positions at very low hydrostatic pressures (<30 mm of H₂O), with the dura in either a lax or tense state. In all the three specimens with dura in a tense state, interrupted stitches leaked at very low hydrostatic pressures (<30 mm of H₂O). In a lax state of the dura, in one specimen, interrupted stitches could withstand a hydrostatic pressure of 52 mm of H₂O, before it leaked. While continuous interlocking stitches also leaked at very low pressure (<30 mm of H₂O) when the dura was tense; in a lax dura, in two specimens, a leak was resisted till 45 and 74 mm of H₂O. Even with a lax dura, the third specimen with continuous interlocking stitches, leaked at a hydrostatic pressure of less than 30 mm of H₂O. In the specimen where a dural substitute was used as an inlay to cover a dural defect, water leaked at a very low pressure (<30 mm of H₂O).

Test results with the needle puncture sites occluded with cyanoacrylate glue [Table 2].

With dura either in lax or tense state, specimens with interrupted or continuous stitches to close a 2 cm incision line withstood a hydrostatic pressure of 240 mm of H₂O, without any leak. Same was true with the specimen with unincised dura with interrupted stitches applied over 2 cm length.

DISCUSSION

The watertight closure of the dura mater is fundamental to intracranial procedures in neurosurgery. Controversies

Table 1: Test results with the needle puncture sites unoccluded

Suture technique	Hydrostatic pressure at saline leak (mm of H ₂ O)					
	Lax dura			Tense dura		
	S1	S2	S3	S1	S2	S3
Interrupted stitches over 02 cm length of intact dura	<30	-	-	<30	-	-
Interrupted stitches on a 02 cm incision line	<30	52	<30	<30	<30	<30
Continuous interlocking stitches on a 02 cm incision line	45	74	<30	<30	<30	<30
In-lay technique using dural substitute	<30	-	-	-	-	-

Table 2: Test results with the needle puncture sites occluded with cyanoacrylate glue

Suture technique	Hydrostatic pressure at saline leak (mm of H ₂ O)	
	Lax dura	Tense dura
	Interrupted stitches over 02 cm length of intact dura	No leak till 240
Interrupted stitches on a 02 cm incision line	No leak till 240	No leak till 240
Continuous interlocking stitches on a 02 cm incision line	No leak till 240	No leak till 240

exist claiming the superiority of one closure technique over another. *In vitro* studies^[1] and experiments on animal studies^[2] have been done to determine the best closure technique. None of these studies have been conducted before with the suture line in the dependent position.

Aim of this study was to determine which one of the two commonly used suturing techniques resulted in a dural closure that leaked less readily with the suture line in the dependent position. A model with multiple interrupted sutures over an intact dura was included to see if the leak could be explained by the needle puncture sites themselves. Unsutured, in-lay closure of a dural defect was also tested for its ability to prevent leak.

In our study, all the suture closure techniques, failed to resist leak, when placed in dependent position against very low pressures. Linear durotomy, over a lax dura, repaired by continuous interlocking stitches fared slightly better (45 mm, 74 mm and <30 mm of H₂O, respectively) as compared to interrupted closure (<30 mm, 52 mm and <30 mm of H₂O, respectively). However, these values are well below the normal range of cerebrospinal fluid pressure (50-100 mm of H₂O) On a single occasion, when interrupted sutures were applied over intact, lax dura, and tested, it leaked at a very low hydrostatic pressure (<30 mm of H₂O), as did all the three attempts at repairing a linear durotomy, on a tense dura with both the

repair techniques. These results indicate that, whatever be the suturing technique, the needle puncture sites are likely to leak at a very low pressure, in dependent position. A dura that is closed under tension is more likely to leak.

In the *in vitro* study conducted by Megyesi F, *et al.*,^[1] the pressure at which 2 cm linear dural incisions leaked was significantly higher when they were closed with the interrupted simple suturing technique. The minimum pressure at which the suture lines leaked was much higher (170 mm of H₂O). However, even in that study, the difference in the ability of different suturing techniques to resist leak was evened out when the pressure over the dura was reapplied for the second time (termed secondary pressure by the author). The secondary leak pressures were lower than the primary leak pressures for all suturing techniques.

These discrepancies can be explained by the fact that the dural suture line was placed on the superior most part of the model. The initial force stretches the suture holes allowing leakage to occur at a lower pressure with the subsequent force.

In the second part of the present study, when the needle puncture sites were closed with cyanoacrylate glue, both the suturing techniques fared well in resisting a hydrostatic pressure of 240 mm of water. An in-lay patch, without any suture/glue, however, failed to resist water leak against a very low pressure (<20 mm of H₂O).

Shortcomings in our study

There were a few obvious shortcomings in our study. First, due to the limitations of our model design, we could not accurately measure the height of the water column, when it was less than 30 mm. We also were unable to test the suturing techniques against a hydrostatic pressure of

more than 240 mm of H₂O. Second, the dura is likely to have dried up during being mounted and subsequently, during various steps in the test, which might potentially have altered the mechanical characteristics of the dura and hence, influenced the outcome. Third, in our experimental model in the dependent position, the dura bulged out under the pressure of the saline over it, stretching the suture lines and the needle pores; which is less likely to occur *in vivo* when the bone flap has been replaced and fixed.

CONCLUSION

With the shortcomings enumerated in the study, one has to be careful in applying the outcomes of this study in practical field. However, since multiple sutures applied over an intact dura also leaked at a very low pressure, when placed in a dependent position, and the sutured linear dural incision can resist leak against a very high hydrostatic pressure when the needle pores are sealed, it seems logical to conclude that: (i) in a properly sutured dural incision, leaks occur primarily from the needle pores, and (ii) in dependent position, dural closure by any technique is likely to leak.

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