

Risk factors for unsuccessful lumbar puncture in children

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Background. This descriptive study provides the first information on an association between the use of sedation and a reduction in the prevalence of unsuccessful lumbar puncture (LP) in African children of all races.

Objective. Our hypothesis was that children who do not receive any procedural sedation are more likely to have unsuccessful LPs.

Methods. A cross-sectional observational study examined LPs performed from February to April 2013, including details of the procedure, sedation or analgesia used, and techniques. The setting was the Medical Emergency Unit at Red Cross War Memorial Children's Hospital, Cape Town, South Africa, and the participants all children aged 0 - 13 years who had an LP in the unit during the time period.

Results. Of 350 children, 62.9% were <12 months of age, the median age being 4.8 months (interquartile range 1.5 - 21.7). The prevalence of unsuccessful (traumatic or dry) LP was 32.3% (113/350). Sedation was used in 107 children (30.6%) and was associated with a reduction in the likelihood of unsuccessful LP ($p=0.002$; risk ratio (RR) 0.5 (95% confidence interval (CI) 0.34 - 0.78)) except in those <3 months of age, where sedation did not significantly reduce the likelihood ($p=0.56$; RR 1.20 (95% CI 0.66 - 2.18)).

Conclusions. Unsuccessful LP was common. Sedation was not routinely used, but the results suggest that it may be associated with a reduction in the rate of unsuccessful LP. Unsuccessful LP may lead to diagnostic uncertainty, prolonged hospitalisation and unnecessary antibiotic use. Whether a procedural sedation protocol would reduce the rate of unsuccessful LP requires further study.

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Bacterial meningitis is a serious disease affecting adults and children, which results in an estimated 180 000 deaths of children aged 1 month - 5 years per year worldwide.^[1] The rapid treatment and diagnosis of meningitis is crucial to reducing morbidity and mortality.^[2] Lumbar punctures (LPs) are commonly performed in paediatric emergency medicine departments to diagnose or exclude meningitis. LPs are considered to be traumatic when red blood cells are introduced into the CSF as a result of needle trauma to the epidural venous plexus lying against the vertebral bodies.^[3] Studies have reported the incidence of traumatic LPs to be between 10% and 30%^[3] using cut-offs of between 400 (which is the visual threshold) and 10 000 red blood cells (RBCs)/ μL . The diagnosis or exclusion of meningitis may be confounded by the presence of any RBCs in the cerebrospinal fluid (CSF), so we chose to use the lowest cut-off of 400 RBCs/ μL in our study. The blood in the CSF sample also results in increased white blood cell (WBC) counts. The WBC count in the CSF is often used to determine whether a patient has meningitis or not. In the era of prehospital antibiotic use, the culture of the CSF cannot be relied upon so WBC counts are used.

Several studies have examined risk factors for unsuccessful or traumatic LP. None examined the influence of sedation on the success of LP. The conclusions with regard to other risk factors were not consistent. Most have agreed that younger patient age (<1 year), not using local anaesthetic, late removal of the stylet and increased patient movement worsen outcomes.^[3-5] The influence of age <3 months and physician experience is less clear.

Unsuccessful LPs are traumatic for the child and parents, especially when repeat procedures are needed. They also cause diagnostic uncertainty which may prolong hospital stay and result in unnecessary antibiotic treatment with cephalosporins, use of which puts the child at risk of acquiring extended-spectrum beta-lactamase-producing organisms.^[6]

Approximately 3 500 LPs are done per year at Red Cross War Memorial Children's Hospital (RCWMCH), Cape Town, South Africa (SA), and in 2009 the proportion of traumatic LPs was found to be 17% of samples sent to the laboratory (R Muloiwa, personal communication, 2014). That study did not include LPs when no samples were sent to the laboratory, so the number of unsuccessful LPs is unknown.

Objective

The high incidence of unsuccessful LPs observed, with the potential adverse consequences of increased hospital stays, led us to undertake an audit of current practice in order to identify what factors may be important in reducing traumatic LPs in our setting. We aimed to identify any modifiable risk factors, including whether the use of sedation is important, as there is currently no evidence for or against this. Using the results of the study we could then introduce a protocol for LPs aimed at reducing the number of unsuccessful LPs and improving the diagnostic yield. It was hoped that this would reduce unnecessary treatment and stay in hospital. There have been no previous studies from Africa addressing the issue of unsuccessful LPs or the use of procedural sedation in children undergoing LP.

Our hypothesis was that children who do not have any procedural sedation are more likely to have an unsuccessful LP.

Methods

This was a cross-sectional observational study. All children who had an LP in the Medical Emergency Unit (MEU) at RCWMCH over a 3-month period were included. Children were excluded if the LP was done in other hospitals or other wards (owing to concerns of bias, as procedures may be different for non-emergency LPs) or if they had

congenital abnormalities of the spine, a history of a bleeding disorder, evidence of vasculitis or cellulitis over the lumbar spine, or a final diagnosis of subarachnoid bleeding from traumatic brain injury or herpes simplex infection on folder review.

The study participants were identified each day by examining the ward registers of the MEU. Children with diagnoses suggesting that they would have had an LP, such as neonatal sepsis, meningitis or fever of unknown origin, were identified and the folders were obtained to see if they had had an attempted LP. The doctors who performed the procedures were then asked to complete a questionnaire detailing the procedure (Appendix 1). The CSF results were obtained from the laboratory. The questionnaires were also available in the department for doctors to complete after any LP they performed. The data capture sheet included patient factors (age, sex), the experience of the person performing the LP and the person holding the child, the needle used, timing of stylet removal, the presence of a family member, any sedation and analgesia used, a rating of the amount of movement of the child, and the result of the procedure. All data were kept anonymous and confidential.

Ethics approval was obtained from the Faculty of Health Sciences Human Research Ethics Committee of the University of Cape Town (HREC ref. no. 173/2013) and from the RCWMCH hospital administration (ref. no. 694/13).

Given an estimated prevalence of unsuccessful LPs of 30%, the study was powered to detect a 50% reduction in the proportion of unsuccessful LPs with the use of sedation with an alpha level of 5%. This was chosen as being a clinically significant reduction. Power analysis demonstrated that 300 subjects would be enrolled for 80% power. The data collected were then analysed using Stata version 13 (StataCorp, USA). Conventional descriptive methods (means and standard deviations, medians with interquartile ranges (IQRs) or proportions) were used to describe and characterise the study population, e.g. gender, age in months, and number of traumatic LPs. The prevalence of unsuccessful LPs in our study was determined. The association between unsuccessful and successful LPs and categorical predictor variables was estimated using generalised linear regression modelling. Owing to the high prevalence (>10%) of the outcome these are reported as risk ratios (RRs) and their respective 95% confidence intervals (CIs).^[7]

Definitions

Traumatic LP: >400 RBCs/ μ L, which is the visual threshold.^[8]

Unsuccessful LP: Traumatic LP or dry, i.e. no CSF obtained.^[3,8]

Early stylet removal: Removal of the stylet after passage through the epidermal and subcutaneous tissues rather than in the subarachnoid space.^[3,5]

Number of attempts: Number of times the needle penetrated the skin (redirecting the needle without exiting the skin is a single attempt).

Experienced holder: Qualified member of staff rather than a student.

Experienced physician: Performed >50 previous LPs.

Results

During the study period, 356 LPs were identified. Repeat procedures following an unsuccessful LP were not included. Data forms were not completed for six of the procedures, so the analysis was done on 350 procedures. Of these patients, 142 (40.6%) were female and 208 (59.4%) male. Of the procedures performed, 220 (62.9%) were on infants <12 months of age and 158 (45.1%) were on infants

<3 months of age. The age range was 3 days - 12.6 years, with a median age of 4.8 months (IQR 1.5 - 21.7).

Of the 350 LPs, 113 were unsuccessful with either dry or bloody taps, giving a prevalence of 32.3% (95% CI 0.27 - 0.37). Of these, four were dry taps and the rest were frank blood or bloodstained CSF (>400 RBCs/ μ L).

Sedation was used in 107/349 cases (30.7%). In one case it was not clear whether sedation had been used or not. Sedation was associated with a reduction in the likelihood of an unsuccessful LP ($p=0.002$; RR 0.5 (95% CI 0.34 - 0.78)). Unsedated patients had a rate of unsuccessful taps of 38.0% compared with 19.6% for patients who were sedated, showing a 51.6% reduction in unsuccessful procedures when sedation was used. Almost all patients who were sedated were given ketamine (93/107, 86.9%), either as a single agent or in combination with midazolam (7 patients). Two patients were given midazolam only. Chloral hydrate was used for 18 patients, alone (12 patients) or in combination with ketamine (6 patients). These numbers were too small to allow statistical comparisons between different methods of sedation.

The use of sedation was strongly correlated with age. Very few infants were given sedation, only 12/158 (7.6%) of those aged <3 months receiving sedation, while 95/191 (49.7%) of those aged \geq 3 months received it ($p<0.001$; RR 2.2 (95% CI 1.89 - 2.65)). Further analysis showed that sedation was not associated with a reduction in the proportion of unsuccessful LPs in infants aged <3 months ($p=0.56$; RR 1.2 (95% CI 0.66 - 2.12)), but the number who received sedation in this age group was very small.

Forty-six of the 107 children who were sedated (43.0%) were said not to be moving at all. Without sedation, 56/242 (23.1%) were said not to be moving at all. Lack of sedation was associated with a significant increase in the rating of how much the child was moving (from 'not at all' to 'a little but did not affect the procedure' to 'a lot - difficult procedure') ($p=0.001$; RR 0.65 (95% CI 0.50 - 0.86)), and increasing movement of the child was associated with a higher proportion of unsuccessful LPs ($p<0.001$; RR 4.08 (95% CI 2.54 - 6.56)).

The data were also analysed to identify other potential factors that may have influenced the outcome of the LP. These are summarised in Table 2.

The strongest predictor of unsuccessful LP was age <12 months. Analysis of patients by age showed that the proportion of unsuccessful LPs increased significantly in infants aged <12 months (Table 3), but there was no further increase in those aged <3 months.^[5]

No significant difference in the rate of unsuccessful LP was found overall when a eutectic mixture of local anaesthetic (EMLA) was or was not used as a local anaesthetic cream for the LP. However, among those patients who received no sedation ($n=242$), the proportion of unsuccessful LPs was 29.4% (15/51) when EMLA was used, whereas those without any analgesia or sedation had a proportion of 40.3% (77/191). This suggests that the proportion of unsuccessful LPs in unsedated patients was reduced when EMLA cream was used, but the numbers using EMLA were small and the reduction was not statistically significant ($p=0.15$; RR 0.73 (95% CI 0.46 - 1.16)).

Of practitioners who used a needle with a stylet, only 15.4% (45/292) removed the stylet early, the rest removing it once in the subarachnoid space. In three cases the timing of the removal of the stylet was unknown. When the stylet was removed early the proportion of unsuccessful LPs was 46.7% (21/45), compared with 30.4% (75/247) with later removal. The number of practitioners who removed the stylet early was small, but this practice was associated

with an increase in the rate of unsuccessful LPs ($p=0.02$, RR 1.54 (95% CI 1.07 - 2.22)).

It was noted that of the procedures where only one attempt was made, 19.0% (32/168) were unsuccessful. When more than one attempt was made the proportion increased to 51.9% (54/104), showing that repeated passes of the needle resulted in an increased risk of unsuccessful LP ($p<0.001$; RR 0.95 (95% CI 0.70 - 1.31)). Use of sedation was not significantly associated with a reduction in the number of procedures requiring more than one attempt ($p=0.47$, RR 0.87 (95% CI 0.59 - 1.27)).

No significant difference was found in the proportion of unsuccessful LPs with increased experience of the physician or holder, presence of a family member, or LPs done during the day as opposed to the night.

Discussion

This observational study provides information on the use of sedation as a risk factor for unsuccessful LP in African children of all races. We are also able to give information on its prevalence in our department. The lower rate of traumatic LP observed by Howard *et al.*^[4] in their study of patients with leukaemia, almost all of whom were sedated, would suggest that sedation is beneficial in reducing traumatic LPs, but this is the first study to compare sedated with non-sedated patients. The 50% reduction in the incidence of unsuccessful LPs when sedation was used in this study leads us to recommend that protocolised sedation be used wherever possible for LP. Sedation has previously been shown to be safe when guidelines are followed,^[9] and the trauma and pain experienced by the child should be reduced if sedation is used.

Table 1. Effect of sedation according to age

Age group	Sedation	N	Prevalence of unsuccessful LP, n (%)		
			n (%)	p-value	RR (95% CI)
<3 months	No	146	61 (41.7)	0.56	1.0 (ref)
	Yes	12	6 (50.0)		1.20 (0.66 - 2.12)
≥3 months	No	96	31 (32.3)	0.01	1.0 (ref)
	Yes	95	15 (15.8)		0.5 (0.28 - 0.85)

Table 2. Predictors of unsuccessful LP estimated by prevalence and RRs (and associated 95% CIs)

Variable		N	Unsuccessful LP, n (%)	p-value	RR (95% CI)
Age	<12 months	220	95 (43.2)	<0.001	1.0 (ref)
	≥12 months	130	18 (13.8)		0.34 (0.22 - 0.53)
EMLA	No	277	91 (32.9)	0.47	1.0 (ref)
	Yes	73	20 (27.4)		0.86 (0.58 - 1.29)
Sedation	No	242	92 (38.2)	2	1.0 (ref)
	Yes	107	20 (18.7)		0.50 (0.34 - 0.78)
Early stylet removal	No	247	74 (30.0)	0.02	1.0 (ref)
	Yes	45	21 (46.7)		1.54 (1.07 - 2.22)
Experience of holder	Student	32	10 (31.3)	0.90	1.0 (ref)
	Staff	318	102 (32.1)		1.04 (0.60 - 1.78)
Movement	None	102	17 (16.7)	0.01	1.0 (ref)
	Some	198	61 (30.8)		1.88 (1.16 - 3.04)
	A lot	50	34 (68.0)		4.08 (2.54 - 6.56)
Experience of physician (LPs performed)	≤50	49	18 (36.7)	0.46	1.0 (ref)
	>50	301	96 (31.9)		0.86 (0.58 - 1.29)
Parental presence	No	322	103 (32.0)	0.68	1.0 (ref)
	Yes	28	10 (35.7)		1.12 (0.66 - 1.88)

EMLA = eutectic mixture of local anaesthetic.

Table 3. Number of procedures for each age range and rates of unsuccessful LP

Age	Procedures, N	% of total	Rate of unsuccessful LP, n (%)	RR (95% CI)
1 - 28 days (neonate)	53	15.1	23 (43.4)	1 (ref)
1 - 3 months	105	30.0	44 (41.9)	0.97 (0.67 - 1.40)
≥3 - 12 months	62	17.7	28 (45.2)	1.05 (0.70 - 1.56)
≥1 - 5 years	85	24.3	13 (15.3)	0.37 (0.22 - 0.64)
≥5 - 13 years	45	12.9	5 (11.1)	0.26 (0.10 - 0.68)
Total	350	100.0	113 (32.3)	

The majority (99.1%) of LPs in our study were done to diagnose or exclude meningitis. Accuracy of diagnosis is crucial for the patient and for the doctor to determine the correct treatment. CSF culture results cannot be relied upon in an era of extensive prehospital antibiotic use due to implementation of the Integrated Management of Childhood Illness (IMCI) guidelines in SA. This means that the WBC count often has to be used for diagnosis of meningitis. Of 350 LPs in this study, only seven had positive CSF cultures. The diagnosis or exclusion of meningitis may be difficult if the LP is unsuccessful. Various correction methods have been proposed to help interpret traumatic LPs, but none of them can be certain to identify all cases of bacterial or tuberculous meningitis.^[3] If blood alone or no CSF is obtained, the LP cannot be used for diagnosis. The 32.3% prevalence of unsuccessful LPs means that the diagnosis may not be clear in one-third of our patients undergoing LP. This may result in repeated procedures, unnecessary treatment, increased costs to the hospital, and increased financial and/or emotional costs for the patient. The rate of 32.3% is consistent with previous studies, although it is one of the higher rates observed.

The factors examined in this study that increased the rate of unsuccessful LP were age <12 months, not using sedation, late removal of the stylet and increased movement of the patient. The finding of age as a predictor of unsuccessful LP is consistent with previous studies.^[4,5,10] In one previous study^[5] an increased incidence in patients aged <3 months compared with those aged 3 - 12 months was also seen, but this was not observed in our study.

Previous studies have shown the benefit to the patient of using local anaesthetic in reducing the pain associated with LP.^[11,12] They have also shown that local anaesthetic increases the success of LP.^[3,5,13] We did not find an increase in success associated with the use of EMLA, but the number of cases in which EMLA was used was small. However, based on previous studies and the known benefits of procedural pain reduction, we would tentatively recommend the use of EMLA for LP.

In previous studies, the Cincinnati method of early stylet removal for LP was associated with increased success rates.^[3,5] In our study success appeared to be associated with late removal, but the number using early removal was small. The reason for the difference in results is unclear. Early stylet removal is not commonly taught in SA, so doctors may not be aware of the different methods and the risks and benefits associated with each. Larger studies are needed to determine which of the methods reduce traumatic taps, as well as the reasons why.

Study limitations

The study had several limitations, including those inherent to audits of current practice. It was a small study, there may have been sampling bias, and there was no randomisation of patients, no use of control groups and no observers of the procedures. Patients received sedation or not according to physician preference or normal practice, which is known to vary and may depend on the availability of monitoring in different areas of the hospital. There may have been recall bias as well as reporting bias because the questionnaires were completed after the LP result was known. Some problems were noted with the questionnaire, one question was often not completed, possibly owing to positioning on the page, and some questions overlapped. As this was not an efficacy study, it was not possible to quantify the risk reduction in absolute terms. For many of the factors examined the numbers in one group were small, so differences may have been missed. The depth of sedation achieved was not assessed and the numbers with each drug at each dose were small, so it was not possible to identify the most effective sedation regimen.

Study implications

This study suggests that the use of sedation is associated with an increase in the success of LP and provides some evidence towards the implementation and further evaluation of protocolised sedation. Further study is needed to determine the ideal medication and the optimal doses, and to assess the effectiveness of sedation in reducing the pain and trauma experienced by the child. Implementation of the use of sedation would require a change in organisation of the unit, with the drugs, monitoring, staff and appropriate environment readily available. This may be a challenge in resource-limited settings. Whether a protocol would then change practice, and whether this would increase success rates, will require further audit. Larger studies are also needed to determine the influence of other procedural factors and whether these can be modified to reduce the rate of unsuccessful LP. As this study was conducted in the medical emergency unit of a children's hospital, the results may not be generalisable to other healthcare facilities dealing with mixed patient loads, but nevertheless highlight the importance of providing procedural analgesia and sedation.

Conclusions

We found that procedural sedation was not routinely used but that it appeared to be associated with a reduction in unsuccessful LPs. The study also revealed a high prevalence of unsuccessful LPs in our institution, with the highest proportion being in infants aged <1 year. Whether a procedural sedation protocol in the MEU would reduce the rate of traumatic LPs, and hence unnecessary treatment and costs, requires further study.

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Appendix 1. Lumbar puncture audit, February 2013

Lumbar puncture audit, February 2013

Date: _____ Time: _____ Patient weight: _____kg

1. Are you a:

Senior registrar	Medical officer/COSMO/SHO
Registrar	Intern

2. How many LPs have you done?

0 - 5	11 - 50
6 - 10	51+

3. Indication for LP:

Exclude meningitis	Reduce intracranial pressure
Measure opening pressure	Monitor response to treatment
Other (specify) _____	

4. Needle used:

Black spinal (22G)	Other spinal (specify) _____
Other needle (specify) _____	

5. Family member present?

Yes	No
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6. Person holding child:

Student nurse	Staff nurse
Sister	Medical student
Doctor	Other _____

7. Sedation and analgesia used – please tick and state dose:

None	EMLA
Lignocaine _____mL	Chloral hydrate _____mg
Ketamine IV _____mg	Ketamine IM _____mg
Midazolam _____mg	Morphine _____mg
Other (specify drug, dose and route) _____	

8. Vital sign monitoring during the procedure? (saturation and heart rate)

Yes

No

9. Was the patient moving?

Not at all

A little but did not affect the procedure

A lot – difficult procedure

10. When did you remove stylet?

When through skin/sub-cut tissue

Subarachnoid space

11. Number of attempts required (i.e. number of times needle penetrated skin): _____

12. LP result

Dry tap

Bloody tap – frank blood

Bloodstained CSF

CSF obtained and sent to lab

For completion by researcher:

LP result

Appearance _____

Polys _____ Lymphs _____ Erythrocytes _____

Glucose _____ Protein _____

Gram stain _____ Culture _____

Post tap headache

Yes

No

Treatment _____

Outcome

Discharged

Treated for meningitis – length stay ____ days

Transfer to _____

Died

Other complication _____