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Original Research Article

Spring loaded syringe versus standard loss of resistance syringe for identification of lumbar epidural space: A randomized controlled study

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Abstract

Background: Epidural anaesthesia is a widely used technique for analgesia and anaesthesia, yet its success depends on accurate identification of the epidural space. The standard loss-of-resistance (LOR) syringe, though effective, requires operator skill and is associated with complications such as dural punctures. The spring-loaded autodetect syringe (SAS) offers continuous pressure and visual confirmation, potentially improving outcomes. This study aimed to compare the efficacy of the SAS and standard LOR syringe in identifying the lumbar epidural space.

Materials and Methods: This randomized controlled study was conducted on 100 ASA I and II patients aged 18–60 years, undergoing lower abdominal and lower limb surgeries. Patients were randomly assigned to the SAS group (n=50) or the standard LOR group (n=50). Time to identify the epidural space (primary outcome), number of attempts, ease of catheter insertion, and incidence of dural punctures (secondary outcomes) were recorded. Statistical analysis was performed using SPSS v24, with $p<0.05$ considered statistically significant.

Results: There were no differences in patient demographics and number of attempts to localize the epidural space between both groups. The time taken to identify the epidural space was significantly faster in the SAS group (48.18 ± 10.46 seconds) compared to the standard LOR group (57.78 ± 17.13 seconds; $p < 0.001$). The number of attempts to localize the epidural space was comparable in both the groups. There was no incidence of inadvertent dural puncture or failed blocks with the SAS.

Conclusion: Identifying the epidural space with spring loaded syringe is simple, quick and reliable compared to standard LOR syringe.

Keywords: Spring loaded autodetect syringe, Loss of resistance syringe, Epidural space, Epidural catheter.

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1. Introduction

Epidural anaesthesia is a cornerstone of pain management in surgeries, obstetric procedures, and chronic pain relief.[1] The success of this technique hinges on the accurate localization of the epidural space, a task traditionally achieved using the Loss-of-Resistance (LOR) method with air or saline as the medium. While widely practiced, the LOR technique is subjective, relying heavily on the operator's tactile perception, which varies with experience and can lead to inconsistent outcomes. This dependency on operator skill presents significant challenges, particularly in anatomically difficult cases such as obesity, scoliosis, or altered spinal anatomy, where tactile feedback may be limited.[2]

The spring-loaded autodetect syringe (SAS) represents a novel advancement designed to address these limitations. Unlike the traditional LOR method, the SAS employs a calibrated spring mechanism to provide consistent, automated pressure during needle advancement.[3] This innovation reduces the reliance on manual force and operator expertise, minimizing variability and enhancing procedural precision. By delivering consistent pressure, the SAS mitigates the risk of excessive force, which could result in dural punctures or tissue damage, and offers greater safety. It also simplifies the learning curve for novice operators, making epidural space localization more accessible across varying skill levels.

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The spring-loaded autodetect syringe (SAS) shows particular promise in challenging clinical scenarios, where the traditional LOR technique often struggles. Preliminary studies suggest that the SAS improves accuracy, safety, and procedural efficiency without requiring additional equipment or expertise, making it a practical and cost-effective solution.[4] This study aimed to evaluate the efficacy, safety, and usability of the SAS compared to the standard LOR technique in a randomized controlled setting.

2. Materials and Methods

This randomized controlled trial was conducted at a tertiary care hospital after obtaining prior approval from the institutional ethics committee, adhering to the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all patients after a detailed explanation of the study objectives, the procedure, and its potential complications. The primary outcome of the study was the time required to localize the epidural space, while secondary outcomes included the number of attempts required, the ease of catheter insertion, and the incidence of dural punctures.

The study included 100 patients classified as ASA I and II, aged 18–60 years, of either sex, who were scheduled for elective lower abdominal and lower limb surgeries. Patients with conditions such as spine deformities, local infections, a history of anticoagulant therapy, pregnancy, a BMI greater than 30, or signs of increased intracranial pressure were excluded from the study. Randomization was achieved using a computer-generated sequence, with allocation concealment ensured through sealed, opaque envelopes. The patients were divided into two groups. In Group SAS, the epidural space was identified using a spring-loaded autodetect syringe with saline (**Figure 1**). While in Group SS, the standard loss of resistance syringe with air was employed (**Figure 2**).

Figure 1: Spring loaded autodetect syringe

Figure 2: Standard LOR syringe

All patients underwent a thorough preoperative evaluation, and fasting protocols were adhered to as per the guidelines of the American Society of Anaesthesiologists (ASA). Premedication with oral alprazolam 0.25 mg was administered the night before and on the day of surgery. On the day of surgery, patients were brought to the operating room, where standard ASA monitors were applied, including electrocardiography, non-invasive blood pressure, and pulse oximetry. Baseline vital parameters were recorded. An 18 G intravenous cannula was inserted into the non-dominant hand, and Ringer lactate infusion was initiated.

Under strict aseptic precautions, the epidural block was administered by an operator who had performed at least 20 successful epidural procedures. The procedure was conducted with the patient in a sitting position using a midline approach. After the epidural needle was fixed and the stylet removed, the respective syringe was attached to identify the epidural space.

In Group SAS, the epidural space was identified using a spring-loaded autodetect syringe with 3 mL of saline (**Figure 3**), while in Group SS, the space was identified using a standard loss of resistance syringe with 3 mL of air. Once the epidural space was located, the catheter was threaded, and a subarachnoid block was performed. The remaining anaesthesia management was conducted according to standard protocols. In cases where epidural anaesthesia failed, general anaesthesia was administered as per standard procedures, and such cases were excluded from statistical analysis.

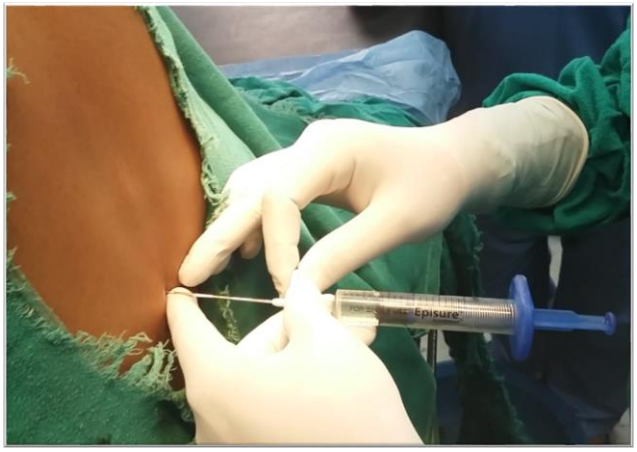

Figure 3: The spring loaded syringe is loaded with saline and attached to the epidural needle

2.1. Statistical analysis

Sample size estimation for this study was based on the results of a study by Johnson et al., which compared the time to reach the epidural space between the Spring-Loaded Autodetect Syringe (SAS) and the standard glass syringe.[5] Johnson et al. reported that the mean time to reach the epidural space using SAS was 31.63 ± 9.4 seconds, while it was 39 ± 14.3 seconds with the standard glass syringe. Using these values as reference, the minimum number of participants required to detect a significant difference in the meantime to reach the epidural space between the two groups, with a power of 80% and a significance level of 5%, was calculated to be 50 patients in each group.

Data analysis was performed using SPSS version 24. Continuous variables were analysed using the independent t-test, while categorical variables were compared using the Chi-square test or Fisher's exact test where appropriate. A p-value of less than 0.05 was considered statistically significant.

3. Results

The demographic parameters, including age, height, weight, and BMI, were comparable between the groups (**Table 1**). Additionally, baseline hemodynamic parameters were similar in both groups, ensuring homogeneity in patient characteristics. The time required to localize the epidural space was significantly shorter in the SAS group (mean ± SD: 48.18 ± 10.46 seconds; median [IQR]: 45 [42–52]) compared to the standard LOR group (57.78 ± 17.13 seconds; median [IQR]: 55 [48–62]; p < 0.001) (**Table 2**).

The number of attempts required to localize the epidural space was comparable between the groups (Figure 4). Although the first-attempt success rate was higher in the SAS group (72%) than in the standard LOR group (68%), the difference was not statistically significant (p = 0.905). A second attempt was required for 15 patients in the standard LOR group and 13 in the SAS group, while one patient in each group required a third attempt.

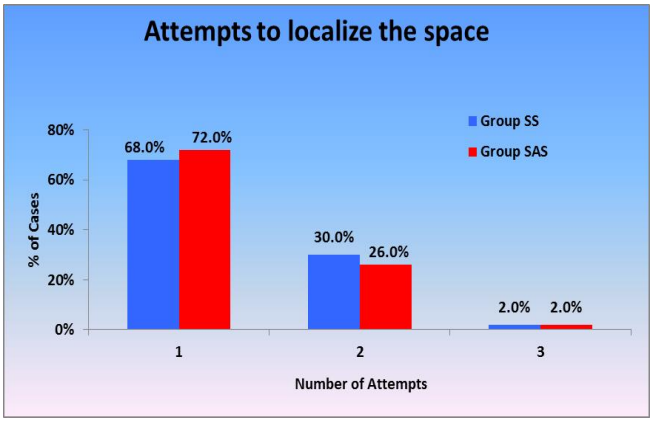

Figure 4: Showing attempts to reach the epidural space was comparable in both the groups

Ease of insertion of epidural catheter was comparable in both the groups. Epidural catheter was inserted without any manipulation of epidural needle in 48 patients in both the groups (grade I) and two patients required intervention (rotation/manipulation of epidural needle) for the passage of catheter (Grade II) in both the groups. (p = 1.000).

There was one case of inadvertent dural puncture in the standard LOR group, whereas no such incidents occurred in the SAS group. However, the difference in the incidence of dural puncture between the groups was not statistically significant (p = 1.000).

Table 1: Comparing demographic profile of the patients in both groups

	Group SS (n=50)		Group SAS (n=50)		p value
	Mean ± SD	**Min - Max**	**Mean ± SD**	**Min – Max**	
Weight (kg)	60.52 ± 9.93	40 - 85	59.28 ± 8.40	44 – 78	0.502
Height(m)	1.59 ± 0.09	1.42 - 1.75	1.59 ± 0.07	1.45 - 1.72	0.720
BMI	23.83 ± 2.95	19.02 - 29.21	23.53 ± 2.54	19.00 - 28.88	0.598

Table 2: Comparison of time taken to reach epidural space in both group

	Group SS (n=50)		Group SAS (n=50)		p value
	Mean ± SD	**Min - Max**	**Mean ± SD**	**Min – Max**	
Time taken to reach epidural space (secs)	57.78 ± 17.13	22 - 96	48.18 ± 10.46	30 – 67	0.001

4. Discussion

Epidural anaesthesia is a widely used technique for providing analgesia and anaesthesia in various surgical procedures, obstetric deliveries, and chronic pain management.[6] Despite its widespread use, identifying the epidural space accurately remains a challenge, especially for inexperienced practitioners. The loss-of-resistance (LOR) technique, introduced by Sicard and Forestier in the early 20th century,[7] remains the most widely used method for identifying the epidural space. This technique relies on tactile feedback to detect a reduction in resistance when the needle enters the epidural space. However, this subjective approach can lead to variability in success rates, especially among novice anesthesiologists.[8,9]

In our study, we found that the spring-loaded syringe significantly reduced the time required to identify the lumbar epidural space compared to the standard LOR syringe. This finding aligns with the results of Johnson et al., who also demonstrated that the spring-loaded syringe enabled faster identification of the epidural space in thoracic epidurals compared to a glass syringe.[5] Similarly, Habib et al. observed that the mean time to locate the epidural space was significantly shorter with the spring-loaded syringe than with the glass syringe.[10]

The shorter time to localize the epidural space using the spring-loaded syringe can be attributed to its design, which allows the operator to control the Tuohy needle with both hands. This enhanced handling improves the precision of needle advancement through the ligamentum flavum, thereby reducing the time required to establish the endpoint of the procedure. Conversely, the standard LOR syringe necessitates intermittent pressure application, which can prolong the process, particularly for less experienced practitioners.

In our study, the first-attempt success rate for epidural space localization was slightly higher in the spring-loaded syringe group compared to the standard LOR syringe group (72% vs. 68%), although this difference was not statistically significant (p = 0.905). This finding contrasts slightly with Johnson et al., who reported a significantly higher first-attempt success rate for thoracic epidurals using the spring-loaded syringe (92%) compared to the glass syringe (76%).[5] The increased success rate observed in Johnson et al.'s study may be attributed to the technical challenges of thoracic epidurals, where the spring-loaded syringe offers better control and precision. Similarly, Mittal et al. reported higher first-attempt success rates using an acoustic puncture assist device compared to the standard LOR technique (84% vs. 80%), though this difference was also statistically insignificant (p = 0.461).[11] These findings collectively suggest that while innovative devices such as the spring-loaded syringe may enhance success rates, the variability in results across studies highlights the critical role of operator skill and technique.

The incidence of inadvertent dural punctures is a significant concern in epidural anaesthesia, as it can lead to complications such as post-dural puncture headaches and, in rare cases, pneumocephalus.[12,13] In our study, one case of dural puncture was reported in the standard LOR syringe group, while no cases occurred in the spring-loaded syringe group, though the difference was not statistically significant (p = 1.000). Supporting these findings, Peach et al. observed a reduced incidence of dural punctures with the spring-loaded syringe, reporting just one case compared to four in the standard LOR syringe group in a study involving 220 participants.[14] Similarly, Johnson et al. found no dural punctures with the spring-loaded syringe in their evaluation of 120 thoracic epidurals, whereas five cases were noted with the glass syringe.[5] Habib et al. also reported zero dural punctures in 325 parturients when using the spring-loaded syringe, compared to four cases with the glass syringe.[10] These results suggest that the spring-loaded syringe may reduce the risk of dural punctures, although further studies are needed to confirm its efficacy across various clinical settings.

The reduced risk of dural punctures with the spring-loaded syringe can be attributed to its design, which applies constant pressure using saline as the medium. This feature enables the needle to stop advancing immediately upon reaching the epidural space, minimizing the risk of dura mater penetration. Additionally, the pressurized saline gently displaces the dura away from the needle tip, providing an added layer of safety. These observations highlight the spring-loaded syringe's potential to enhance the safety and reliability of epidural procedures.

Faster identification of the epidural space with the spring-loaded syringe offers significant clinical benefits by reducing procedure time. This advantage is particularly valuable in high-risk patients or emergency settings, where time is a critical factor. Moreover, the device may prove beneficial in challenging cases, such as patients with obesity or complex anatomical variations, though further research is necessary to fully explore its potential in such contexts.

However, the novel mechanism of the spring-loaded syringe may require a steeper learning curve for practitioners unfamiliar with its use. Structured training programs designed to improve user familiarity and proficiency could facilitate broader adoption and maximize its clinical utility.[5,13]

The choice of medium in the loss of resistance (LOR) technique significantly influences the safety and efficacy of epidural space localization. Saline, being incompressible, provides a clear and immediate endpoint upon reaching the epidural space. In contrast, air, due to its compressibility, may lead to false positives and complications, such as venous air embolism or pneumocephalus, if injected in large volumes. Although saline may dilute local anaesthetics when overused, its advantages in reducing complications and improving accuracy outweigh this drawback in most cases. The spring-loaded syringe, designed for use with saline, leverages these benefits to deliver consistent and reliable results.[15,16]

While the study demonstrated the advantages of the spring-loaded syringe, certain limitations must be acknowledged. The relatively small sample size and single-centre design may restrict the generalizability of the findings. Furthermore, the study focused exclusively on lumbar epidurals, and the results may not directly apply to thoracic or cervical epidurals, which present unique technical challenges. Future multicenter studies with larger sample sizes are essential to validate these findings and investigate the broader applicability of the spring-loaded syringe in diverse clinical settings.

5. Conclusion

The spring-loaded autodetect syringe is a reliable, efficient, and safe alternative to the standard LOR syringe for identifying the epidural space. Its advantages in reducing procedure time, enhancing needle stability, and minimizing complications make it a valuable tool in epidural anaesthesia practice. However, further multicenter studies are needed to validate these findings and establish its efficacy across diverse patient populations and clinical scenarios.

6. Sources of Funding

None.

7. Conflict of Interest

None.

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