Electromagnetic Navigation in Biportal Endoscopic Lumbar Spine Surgery

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Abstract:

Introduction: Endoscopic Spine Surgery (ESS) has begun to gain traction as an alternative to traditional microscopic spine surgery, particularly for lumbar decompression. However, one of the challenges associated with this approach is the steep learning curve. A recent advancement in this field aims to flatten the learning curve by incorporating navigation into ESS. This technology provides valuable information on the extent of decompression, confirms the working level, and reduces radiation exposure.

Technical Note: We aimed to describe our experience using electromagnetic navigation in biportal endoscopic spine surgery (BESS). The surgical technique is initiated by positioning the patient prone on a radiolucent table. The navigation field generator is positioned over the caudal end of the patient. The navigation system is set up with patient mappers at the desired working levels. The patient tracker is implanted. The final fluoroscopy images are captured in anteroposterior and lateral views. Subsequently, standard incisions are made, and endoscopic decompression is performed. When required, various instruments can be used to confirm the level, angulation, and extent of decompression.

Conclusions: Our experience showed that this approach reduced the need for intraoperative imaging and provided an accurate alternative to repeated intraoperative imaging. However, it does involve a significantly long setup. Further trials of larger scale are required to determine its efficacy.

Keywords:

Endoscopic spine surgery, minimally invasive, electromagnetic navigation, learning curve, decompression, biportal endoscopic spine surgery

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Introduction

With the global increase in the elderly population, spinal disorders have become prevalent[1]. This debilitating condition is characterized by significant pain in the lumbar and gluteal regions, along with numbness and claudication symptoms, and significantly impacts patients' quality of life[2,3]. Surgical interventions have traditionally been less preferred for these patients because of advanced age and numerous medical issues leading to unfavorable outcomes[4]. Endoscopic spine surgery (ESS) has emerged as a promising remedy for this issue, providing a minimally invasive alternative to conventional open surgical approaches for treating a range of spinal disorders. The scope of this approach is continually expanding alongside advancements in endoscopic instruments, broadening the indications[5]. ESS offers numerous advantages, including smaller incisions, less tissue damage, shorter hospital stays, and faster recovery times[6]. However, this approach presents a unique set of challenges, such as limited visibility and the need for precise instrument placement in complex spinal anatomy.

Navigation systems have been introduced to address these challenges and improve the accuracy and safety of ESS. These systems provide real-time guidance during procedures, enabling surgeons to navigate the intricate spinal anatomy with greater precision. By enhancing visualization and instrument placement, navigation systems can improve surgical outcomes and reduce the risk of complications[7].

Several studies have investigated the use of navigation in ESS, demonstrating its effectiveness in improving accuracy,

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reducing radiation exposure, and enhancing surgical efficiency. For example, Zhao et al. found that navigation-assisted endoscopic lumbar discectomy resulted in shorter operative times and lower radiation exposure compared with conventional fluoroscopy-guided techniques[8]. Another study by Choi et al. reported improved clinical outcomes and reduced complication rates with navigation-guided endoscopic spinal surgery[9].

Overall, navigation systems have demonstrated potential in improving the safety and effectiveness of ESS, making the procedure more accessible for emerging surgeons adopting this relatively new technique. Therefore, we would like to share our insights and experiences with using electromagnetic (EM) navigation in biportal endoscopic spine surgery (BESS).

The navigation system of the joimax® Intracs® em was used in BESS. The navigation system uses an EM tracking system that allows the live tracking of compatible surgical instruments without the need for repeated radiography. The display reveals the exact position and orientation of the compatible instruments relative to the patient in the intraoperative acquired radiograph images. The advantages of EM navigation over optical navigation include the lack of movement restrictions, as optical navigation requires a continuous line of sight, and reduced radiation exposure due to fewer repeated intraoperative radiographic shots compared with traditional radiographs[10,11]. The main aim of this technical note is to describe the advantages and challenges encountered when using this navigation system in BESS.

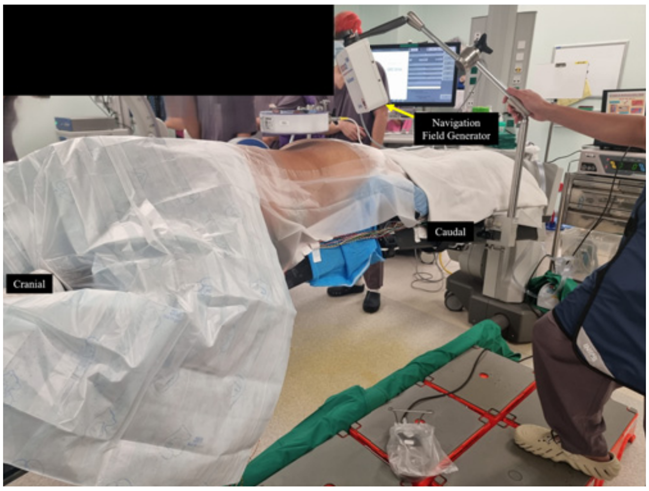

Figure 1. Operating theatre setup showing the navigation field generator secured with holding arms at the caudal end oriented toward the patient.

Technical Report

The patient is intubated and placed under general anesthesia as per the common practice for ESS. Subsequently, they are placed on a radiolucent table. We used a ProAxis® table; however, the system is compatible with other commonly used operating tables, such as the Trumpf® and Maquet® operating tables. The navigation field generator is secured with the mounting arm at the caudal end and directed downward toward the patient, approximately 30 cm from the patient. The field generator emits a low-intensity electromagnetic field that defines the tracking volume of the EM navigation system. The operating theater layout is illustrated in Fig. 1.

The patient mappers are subsequently positioned at the targeted working level. In this case, we performed multilevel decompression of the left L4/L5 and L5/S1 segments. Because we were still accustomed to the system, we verified and marked the placement of the patient mappers using conventional intraoperative radiographs to ensure their optimal positioning during registration, as shown in Fig. 2. This step can be skipped if the surgeon is more familiar with the system.

The mappers are then brought out of the field, and the C-

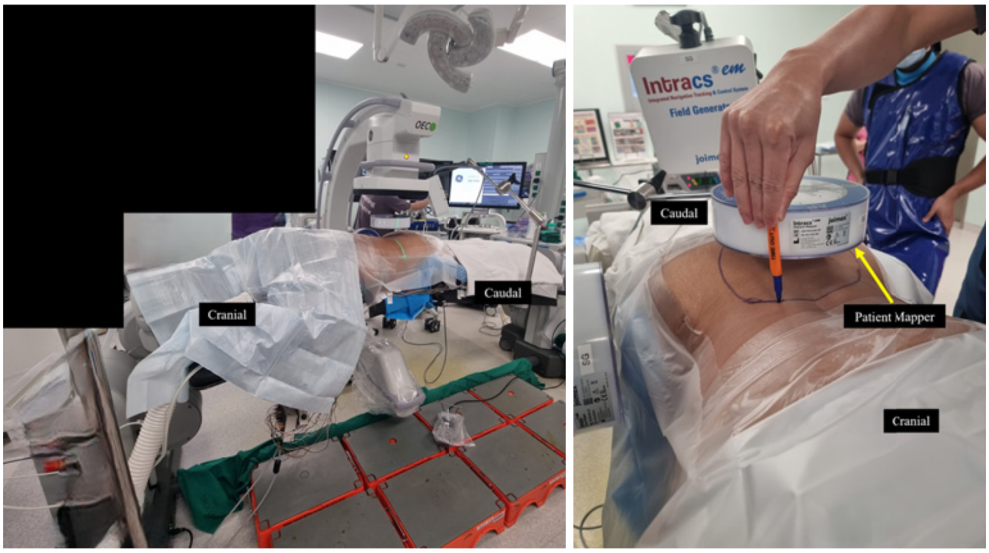

Figure 2. Optimal placement for the patient mapper with the C-arm and marking of the position using a skin marker.

arm is used to identify the optimal skin incision site. A routine skin incision for BESS was made 1 cm above and below the disc space along the interpedicular line between the left L4, L5, and S1 vertebrae, as shown in Fig. 3. This step can be omitted if the surgeon chooses to use the provided navigable needle to determine the optimal skin incision. The C-arm is then removed from the field, and the patient is draped with the field generator and patient mapper.

After the patient is cleaned and draped, the patient tracker is implanted into the iliac crest using K-wires. Alternatively, it can be implanted into the spinous process near the working area, depending on the surgeon's preference. The patient tracker should sit flush against the skin to ensure accurate registration of the components. The protruding K-wires should be cut flush with the patient tracker to prevent interference during surgery (Fig. 4).

The patient mapper is repositioned in the operating field at the previously marked level. Anteroposterior and lateral C-arm images are captured at the desired working level and uploaded to the control unit for registration (Fig. 5).

Once registration was complete, real-time navigation was readily available. The navigable instruments require registration on the patient tracker only once before use, and multiple instruments can be used concurrently as long as they are in the EM field. We mainly used the supplied navigable needle to determine the extent of decompression and confirm the level at which we were operating in the spinal canal without the need for repeated C-arm shots. The surgeon's view is illustrated in Fig. 6, and the navigable instrument is shown in Fig. 7.

Routine endoscopic decompression is then performed with the surgeon having the ability to use the navigable instruments at any time. Additionally, the navigation system allows a target point to be set based on the radiograph images. The target point guides the surgeon to the desired location in the body, as shown in Fig. 8, where the surgeon aims to access the interlaminar space of the L4/L5 vertebra for decompression.

Figure 3. Skin incisions marked for BESS at left L4/L5 and L5/S1.

Figure 4. Patient trackers secured to the iliac crest close to the patient's skin surface and protruding K-wires are cut flush to the patient tracker.

Figure 5. Anteroposterior and lateral C-arm images captured with the patient mapper positioned in the target working area.

Discussion

We had a largely positive experience using EM navigation in BESS, as it offers several significant advantages, particularly in terms of accuracy, radiation exposure, and ergonomics. One of the key benefits of real-time navigation is the enhanced accuracy, which allows for more precise instrument placement than traditional 2D fluoroscopy. Conventional 2D fluoroscopy has the disadvantage of not offering real-time navigation, requiring the surgeon to pause the procedure and potentially step away from the surgical field to obtain images[12,13]. This interruption can lead to less accurate navigation and poor ergonomics, as the surgeon must repeatedly leave the field, especially in multilevel decompression cases, as described above.

Another significant advantage is the reduction in radiation exposure. Electromagnetic navigation eliminates the need for repeated fluoroscopy shots, which not only decreases the radiation dose to the patient but also minimizes exposure to the surgical team. This is particularly critical in multilevel decompression or discectomy, in which the surgeon relies on repeated anteroposterior (AP) and lateral radiographs to confirm the precise positioning of the cannula and endoscopic instruments. In addition, previous studies have shown that minimally invasive (MIS) surgeons are at a higher risk of developing cataracts or even solid organ tumors compared with those performing more invasive techniques that rely less on image guidance[14].

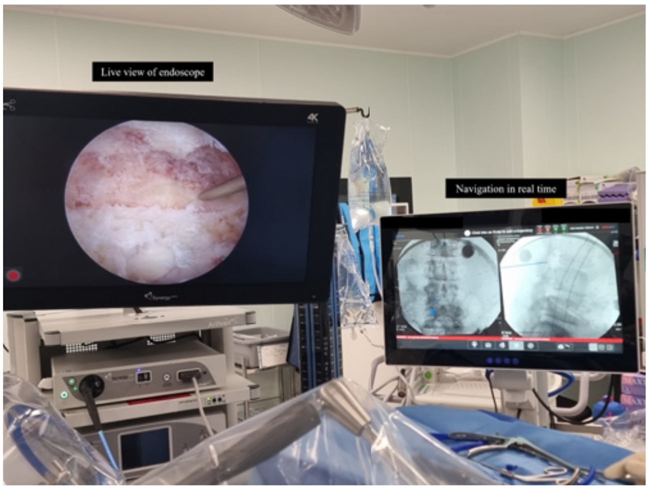

Figure 6. Surgeon's perspective with navigable instruments introduced into the field, alongside the endoscope and navigation system enabled.

When comparing EM navigation to optical systems, a key issue with optical systems is their reliance on a continuous line of sight between the surgical field and tracking camera. The reflective marker spheres must be visualized directly to maintain accurate navigation. Additionally, these marker spheres are typically attached to the instrument handles, making it nearly impossible to navigate the flexible needle tips while maintaining line of sight. EM navigation addresses these challenges. It provides accuracy comparable to that of optical navigation without line of sight limitations, thus giving the operating surgeon more freedom[15]. Trainees no longer need to worry about line of sight issues; they can focus on the surgery, thus potentially improving the learning curve. In addition, Wu et al. demonstrated that procedure time and cannula placement time were significantly faster in the EM navigation group compared to conventional fluoroscopy in transforaminal endoscopic lumbar decompression, while also reducing radiation exposure[13]. This enhanced precision is crucial for BESS because the steep learning curve is a major barrier to its wider adoption, potentially discouraging new spine surgeons from attempting it.

However, a significant drawback of electromagnetic navigation is the lengthy setup time. We took 20 to 30 min to prepare the additional required instruments. This extended preparation can be disadvantageous, especially in busy surgical environments where time efficiency is crucial. With increased familiarity among the surgical team and operating theatre staff, setup times could be improved. The cost of electromagnetic navigation compared to other navigation options has not been extensively documented, making it an important factor to consider.

Conclusion

Although electromagnetic navigation in BESS has some

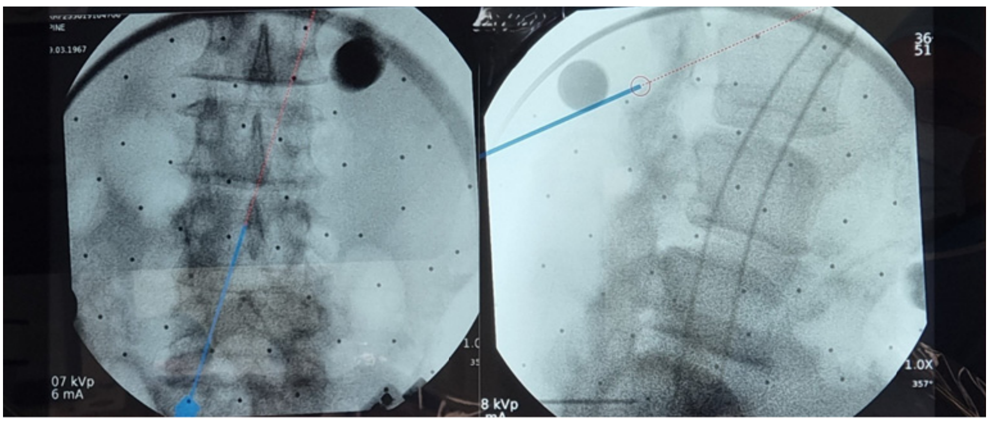

Figure 7. Navigable needle (blue), with the red circle indicating the tip of the needle.

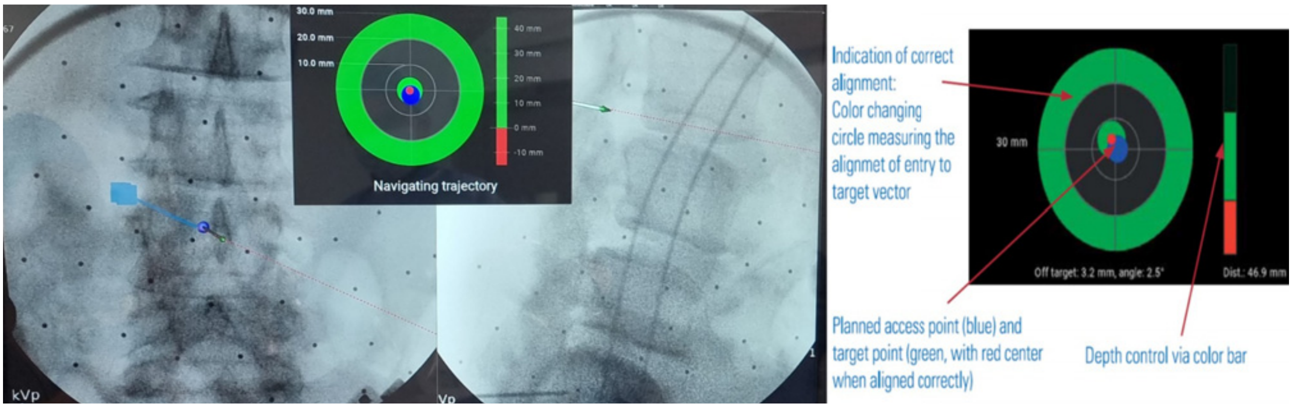

Figure 8. Visualization of the set target vector with an explanation of the navigating trajectory image.

challenges, its benefits in accuracy, safety, and visualization make it a valuable tool for trainee doctors performing ESS and experienced spine surgeons. The proposed method also has the potential to encourage the broader adoption of ESS by helping to reduce the steep learning curve.

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Informed Consent: Informed consent for publication was obtained from all participants in this study.

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