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Clinical Studies

Feasibility of outpatient robot assisted minimally invasive transforaminal lumbar interbody fusion

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ABSTRACT

Introduction: Lumbar interbody fusion is a common spine procedure. 199,140 elective lumbar fusions were performed in the United States in 2015. Robot assisted (RA) pedicle screw placement has advanced minimally invasive spine surgery (MIS) making short stay transforaminal lumbar interbody fusions (TLIF) with same day or next day discharge a possibility for select patients.

Methods: This study is a retrospective case series of a single surgeon's experience with RA MIS TLIF using the Globus ExcelsiusGPS system. Patients undergoing RA MIS TLIF at an outpatient surgery center between August 2020 and February 2021 were included in the study.

Results: Twenty-three patients met inclusion criteria. Ninety-six RA pedicle screws and 25 interbody cages were placed. 96/96 (100%) pedicle screws and 25/25 (100%) interbodies were found to be in satisfactory position using intraoperative x-ray. None of the instrumentation required re-placement or revision intraoperatively. 20/23 (87%) patients were able to discharge within 24 hours of the procedure. 2/23 (8.7%) patients discharged on the day of surgery. One patient of 23 (4.3%) required discharge to an inpatient rehabilitation facility post operatively. 0/23 (0%) patients required readmission for pain control.

Conclusions: Our study demonstrates the safety and feasibility of outpatient RA MIS TLIF for select patients. Future directions include a larger study to elucidate characteristics of the best candidates for outpatient RA MIS TLIF.

Background

Lumbar interbody fusion (LIF) is a well-recognized treatment option for a multitude of spinal pathologies, including trauma, infection, neoplastic and degenerative disease. LIF includes placement of a structural graft within the intervertebral disc space after performing a discectomy with endplate preparation [1]. Currently, LIF can be performed using several approaches including anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), oblique lumbar interbody fusion (OLIF), and lateral lumbar interbody fusion (LLIF).

There is some uncertainty in the literature regarding superiority of interbody fusions compared to posterolateral fusion only for adult degenerative spondylolisthesis [2]. Although the existing literature varies regarding the superiority of one specific approach, interbody fusion is preferred by many clinicians over the traditional posterolateral fusion. The surgical approach and decision whether to use an interbody device is likely a result of a combination of considerations including patient factors, surgeon experience, and cost. In 2015, 199,140 (or 79.8 per 100,000) elective lumbar fusions were performed [3], a 62.3% increase from the year 2004. The greatest increase in procedures was found among patients aged 65 and older, with a total of 170.3 lumbar fusions per 100,000 individuals aged 65 or older [4].

Historically, lumbar fusions such as the transforaminal interbody fusion (TLIF) have been performed via an open approach. Over the last decade minimally invasive approaches have emerged and have been employed more frequently due to promising quality improvement both peri and postoperatively with many patients having an opportunity for discharge within 24 hours of surgery [5,6]. With the advent of minimally invasive approaches including transforaminal interbody fusion (MI-TLIF) and stereotactic computed tomography (CT) guided robot assisted (RA) surgery, the accuracy of pedicle screw placement has increased as compared to the open approach allowing for reduced operative morbidity and complications [7–9].

FDA device/drug status: Not applicable.

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Table 1
Patient demographics.

Demographic	Number
Patients	23
Mean age(standard deviation)	58 (11.34)
Male	5 (21.7%)
Female	18 (78.3%)
Body Mass Index(standard deviation)	33.5 (7.8)

MI-TLIF of both types has advantages in operative time, EBL, post-operative pain, recovery, and long-term paraspinal muscle atrophy [3]. In addition, patients undergoing MI-TLIF have experienced significant improvement in visual analogue scale (VAS) scores for leg and back pain, return to work time, and less narcotic use as compared to the open approach [10]. Compared to other TLIF approaches, both open and minimally invasive, the utilization of RA lumbar fusion surgery has demonstrated a statistically significant benefit in reduced rates of lumbar pedicle screw placement revision [6]. Furthermore, recent literature evaluating the two types of minimally invasive spinal fusions; robot assisted fusions and fluoroscopy guided fusions, has shown differences in both peri and post-operative outcomes between the two groups. Evidence from these studies supports superior outcomes in the robot assisted groups [5,7]. As compared to fluoroscopy guided fusion, robot assisted lumbar fusion has been shown to decrease the risk of surgical complications by 5.8 times and decrease the risk of surgical revision by 11.0 times [11]. Thus, there is a need to identify factors contributing to improved patient outcomes with robot-assisted lumbar fusion. The aim of our study was to demonstrate the safety and feasibility of performing RA MIS TLIF on an extended-recovery basis (less than 24 hour inpatient stay) in a surgery center environment.

Methods

This is a single institution, retrospective study evaluating a single surgeon's experience with RA MI-TLIF using the ExcelsiusGPS system by Globus Medical (Audubon, PA). The first 23 consecutive adult patients who underwent single-level and two-level RA MIS TLIF at an outpatient surgery center between August 2020 and February 2021 were included in the study. Patients who underwent prior spinal instrumentation procedures were excluded. Patient demographics (age, sex, BMI, fusion levels, etx) and pre/postoperative imaging were obtained from the electronic medical record.

Procedure: Stereotactic CT of the lumbar spine was obtained for each patient preoperatively to allow for pedicle screw placement planning and efficient surgical workflow. The patient was positioned prone on the operating table with stereotactic arrays placed bilaterally in the posterior superior iliac spine. Intraoperative fluoroscopic views of the intended surgical levels were obtained and merged with the preoperative CT. Pedicle screw trajectories were planned using the ExcelsiusGPS software and placed percutaneously with the robotic arm without the use of a Kirschner wire bilaterally. Fig. 1 shows a surgeon placing a percutaneous pedicle screw using robot assistance. Expandable interbody placement was performed via a 22 mm tubular retractor after sequential muscle dilation. Following interbody insertion and expansion, lordotic curved rods were inserted and secured with set screws. Screw placement accuracy was determined with postoperative x-ray, which demonstrated good screw positioning without breach.

Results

After querying our electronic medical record, twenty-three patients met inclusion criteria. Patient demographics are shown in Table 1. Of the total patients included, 21.7% of the patients were male and 78.3% were female. The mean age was 58 years (standard deviation 11.3). Average BMI was 33.5 (+/- 7.8 standard deviation). Two (8.7%) of the patients in this study underwent two level RA MIS TLIF. The remaining 21 patients underwent single level procedures. The most common level was L4/5 making up 76% of the fusions. Numerical results are summarized in Tables 2 and 3. In total, ninety-six RA pedicle screws and 25 expandable interbody cages were placed. All pedicle screw and interbody placements were found to be in satisfactory position using intraoperative imaging. None of the instrumentation required repositioning or revision.

Twenty of the 23 (87%) patients were able to discharge within 24 hours of the procedure, with two of the 23 (8.7%) patients discharged on the day of surgery. Two patients (8.7%) were discharged home on postoperative day two and one patient (4.3%) discharged on postoperative

Fig. 1. Robot assisted placement of a lumbar percutaneous pedicle screw.

Table 2
Summary of number of screws and interbody devices placed. Number of patients who discharged to inpatient rehabilitation (IPR).

Result	Number
L3/4 level	2 (8%)
L4/5 level	19 (76%)
L5/S1 level	4 (16%)
Total interbody grafts	25
Total pedicle screws placed	96
Total pedicle screws repositioned	0
Estimated blood loss mL(standard deviation)	67 (96.7)
Operative time minutes(standard deviation)	135.8 (28)
Patients discharged to IPR	1 (4.3%)

Table 3
Number of patients categorized by post-operative discharge day.

Post-operative Discharge Day	Number of Patients
0	2 (8.7%)
1	18 (78.3%)
2	2 (8.7%)
3	1 (4.3%)

day three. Twenty-two of 23 patients (95.6%) were discharged home following their short postoperative stay, whereas one patient (4.3%) required discharge to an inpatient rehabilitation facility post operatively. This patient required inpatient rehabilitation due to pain and gait difficulty. No patient required readmission for postoperative pain control. One patient required surgical intervention for evacuation of a spinal epidural hematoma on post-operative day 2. This patient initially discharged home on POD 1. However, the patient developed mild left lower extremity weakness and bilateral lower extremity paresthesias. Following surgical evacuation, the patient's symptoms resolved. No infections occurred in our study population.

Discussion

Minimally invasive spine (MIS) procedures have become common procedures for numerous spinal pathologies. The advancement in MIS surgery has allowed for patients to undergo surgical intervention with reduced operative loss, less muscular dissection, faster recovery, and fewer complications. The introduction of robot assisted pedicle screw placement has also allowed surgeons to perform accurate pedicle screw placement for lumbar fusion that is effective and safe.

In the present study, the authors have demonstrated the feasibility and safety of utilizing robotics to perform RA MIS TLIF. As demonstrated by recent literature, MIS spine surgery shows significant improvement in patient VAS, return to work time, and narcotic usage. The introduction of robot assisted techniques for MIS has been shown to increase accuracy of pedicle screw placement [3,7,12-15]. These procedures can be safely performed in outpatient surgery centers.

Ninety-six RA MIS pedicle screws were placed in this study with none of them requiring revision. This illustrates the accuracy of RA pedicle screw placement which has been demonstrated in other larger studies. Previous studies have demonstrated the feasibility of same day discharge following MIS TLIF [5,16,17]. 87% of the patients in our small case series were able to be discharged within 24 hours. RA MIS TLIF provides is an alternative MIS technique which may facilitate performing these procedures in the outpatient setting due to the increased accuracy of RA pedicle screw placement. Our results also demonstrate that operative time and estimated blood loss are within reasonable limits for RA MIS TLIF. The cohort of patients included in the study were all taken from within the first 100 RA spine surgeries at our institution. As we gain more experience with RA technique, operative time is expected to decrease as efficiency improves. Minimizing the number of patients admitted following MIS TLIF improves the efficiency of utilization of healthcare resources and allows patients to recover at home in their usual surroundings.

There was only one complication in this cohort of patients. She ultimately recovered fully following evacuation of the epidural hematoma. However, this does illustrate the importance of meticulous hemostasis when performing MIS procedures.

Patient selection is important when determining who is a candidate for outpatient surgeries. Our selection criteria included patients undergoing 1 and 2 level MIS lumbar fusions. All open approaches are performed at the main hospital. Patients with significant cardiac or pulmonary comorbidities were excluded from outpatient surgery. The anesthesiologist also evaluated the patient to determine whether there are any additional health factors that would preclude performing the surgery in the outpatient center. The anesthesia policy specifically excludes patients with insulin pumps from undergoing surgery at the outpatient center.

Implementing any new technique or technology does have a learning curve for the surgeon and operating room staff. Ease of use will vary by the specific system being used. The Globus robot navigation system is relatively simple to use. It takes approximately 3-5 surgeries to become familiar with the interface and workflow of the robot. Minor efficiency improvements continue over the next 20-30 operations. Supporting the robot is also relatively simple from the operating room support staff perspective. Draping the robot arm and positioning it in the operative field are the only additional tasks necessary compared to standard MIS navigated pedicle screws. The drape is a simple sleeve over the robot arm. Therefore, no special training is required for operating room staff.

The registration method used in our surgical workflow is an important factor which keeps operative time low. We obtain a stereotactic CT scan prior to surgery. Intraoperative registration is performed by obtaining anterior-posterior and lateral radiographs using the C-arm with fiducial markers in place. The radiographs are then fused to the CT images. This eliminates the need for an intraoperative O-arm spin which is time consuming and can be cumbersome in smaller operating rooms. Additionally, by obtaining the stereotactic CT prior to surgery, pedicle screw trajectories can be planned prior to the start of the procedure. These small efficiency gains facilitate keeping operative times to a minimum.

The focus of this article is on the technical feasibility of outpatient RA MIS TLIF procedures. However, it is important to note that robot systems do require significant financial investment. Purchasing a new Globus robot navigation system requires a capital investment of approximately $800,000 to $1,000,000. This includes the robot and associated instrumentation. Annual maintenance costs are typically between $30,000-$40,000. The significant financial investment will likely limit the early adoption of RA spine surgery to large, high-volume centers.

Conclusions

The present study demonstrates the safety and feasibility of performing outpatient RA MIS TLIF for select patients. The primary limitations of this case series include the small patient sample size and the retrospective nature of the study. Future directions include a larger study to further elucidate characteristics of the ideal candidates for outpatient RA MIS TLIF.

Disclosures

The authors have no disclosures.

Summary sentence

This article presents a series of patients who underwent minimally invasive transforaminal lumbar interbody fusions using robot-assisted pedicle screw placement at an outpatient surgery center demonstrating feasibility of performing these procedures in an outpatient setting.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100192.

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