The Institute for Healthcare Improvement–NeuroPoint Alliance collaboration to decrease length of stay and readmission after lumbar spine fusion: using national registries to design quality improvement protocols

Scott L. Zuckerman, MD, MPH,1 Clinton J. Devin, MD,2,3 Vincent Rossi, MD,4 Silky Chotai, MD,1 E. Hunter Dyer, MD,4 John J. Knightly, MD,4 Eric A. Potts, MD,6 Kevin T. Foley, MD,7 Erica F. Bisson, MD,8 Steven D. Glassman, MD,9 Praveen V. Mummaneni, MD,10 Mohamad Bydon, MD,11 and Anthony L. Asher, MD4

Departments of 1Neurological Surgery and 2Orthopaedic Surgery, Vanderbilt University Medical Center, Nashville, Tennessee; 3Steamboat Orthopaedic and Spine Institute, Steamboat Springs, Colorado; 4Carolina Neurosurgery & Spine Associates, Neuroscience and Musculoskeletal Institutes, Atrium Health Charlotte, North Carolina; 5Atlantic NeuroSurgical Specialists, Morristown, New Jersey; 6Goodman Campbell Brain and Spine, University of Indiana, Indianapolis, Indiana; 7Department of Neurosurgery, University of Tennessee, Semmes-Murphey Neurologic and Spine Institute, Memphis, Tennessee; 8Department of Neurosurgery, University of Utah, Salt Lake City, Utah; 9Norton Leatherman Spine Center, Norton Healthcare, Louisville, Kentucky; 10Department of Neurosurgery, University of California, San Francisco, California; and 11Department of Neurological Surgery, Mayo Clinic, Rochester, Minnesota

OBJECTIVE National databases collect large amounts of clinical information, yet application of these data can be challenging. The authors present the NeuroPoint Alliance and Institute for Healthcare Improvement (NPA-IHI) program as a novel attempt to create a quality improvement (QI) tool informed through registry data to improve the quality of care delivered. Reducing the length of stay (LOS) and readmission after elective lumbar fusion was chosen as the pilot module.

METHODS The NPA-IHI program prospectively enrolled patients undergoing elective 1- to 3-level lumbar fusions across 8 institutions. A three-pronged approach was taken that included the following phases: 1) Research Phase, 2) Development Phase, and 3) Implementation Phase. Primary outcomes were LOS and readmission. From January to June 2017, a learning system was created utilizing monthly conference calls, weekly data submission, and continuous refinement of the proposed QI tool. Nonparametric tests were used to assess the impact of the QI intervention.

RESULTS The novel QI tool included the following three areas of intervention: 1) preoperative discharge assessment (location, date, and instructions), 2) inpatient changes (LOS rounding checklist, daily huddle, and pain assessments), and 3) postdischarge calls (pain, primary care follow-up, and satisfaction). A total of 209 patients were enrolled, and the most common procedure was a posterior laminectomy/fusion (60.2%). Seven patients (3.3%) were readmitted during the study period. Preoperative discharge planning was completed for 129 patients (61.7%). A shorter median LOS was seen in those with a known preoperative discharge date (67 vs 80 hours, p = 0.018) and clear discharge instructions (71 vs 81 hours, p = 0.030). Patients with a known preoperative discharge plan also reported significantly increased satisfaction (8.0 vs 7.0, p = 0.028), and clear discharge instructions (71 vs 81 hours, p = 0.030). Patients with a known preoperative discharge plan also reported significantly increased satisfaction (8.0 vs 7.0, p = 0.028), and clear discharge instructions (71 vs 81 hours, p = 0.030). Patients with a known preoperative discharge plan also reported significantly increased satisfaction (8.0 vs 7.0, p = 0.028), and clear discharge instructions (71 vs 81 hours, p = 0.030). Those receiving postdischarge calls (76%) had a significantly shorter LOS than those without postdischarge calls (75 vs 99 hours, p = 0.020), although no significant relationship was seen between postdischarge calls and readmission (p = 0.342).

CONCLUSIONS The NPA-IHI program showed that preoperative discharge planning and postdischarge calls have the potential to reduce LOS and improve satisfaction after elective lumbar fusion. It is our hope that neurosurgical providers...
CLINICAL registries have become a mainstay of neurosurgical research throughout the last decade. In 2012, the AANS in conjunction with the NeuroPoint Alliance (NPA) launched the Quality Outcomes Database (QOD), a registry effort that has grown into the largest North American cooperative data collection tool. The most robust arm of the QOD is the Spine Registry, drawing from 110 participating centers across 36 states, that tracks the quality of surgical care for common spinal procedures. Registries are especially important given the unreliability of procedural randomized controlled trials. However, translating registry data into tangible improvement has proved difficult.

The reporting of high-value data alone is unlikely to affect change. In a recent editorial, Berwick summarized two studies that compared outcomes between hospitals involved in clinical databases with those without database involvement and found comparable rates of serious complications and mortality. Berwick concluded, “end results information, although necessary for improvement, is not sufficient” and proposed that data collection and analysis versus applied quality improvement (QI) represent two distinct intellectual and practical competencies. Berwick’s enhanced model for achieving improvements in care suggests that we must invest in processes that foster activities of learning, skill building, and change among care providers within participating healthcare institutions.

Spine care represents precisely the high cost, high variability surgical intervention to test incorporation of applied QI into registries. In recent decades, lumbar spine surgeries have increased by 300% and now total approximately 67% of neurosurgical practice. Total spine costs exceed $200 billion, and the greatest proportion of overall healthcare expenditure in US hospitals is spent on spinal fusion. While outcomes achieved with surgery are excellent at a group level, tremendous individual variation exists regarding length of stay (LOS) and readmission, leaving significant room for improvement.

While some centers have described streamlined clinical care pathways and multidisciplinary QI initiatives, these have generally been single-institution experiences comprising smaller samples. Currently, registry models of continuous data collection, analysis, QI application, and iterative development are lacking. We present the NPA partnership with the Institute for Healthcare Improvement (NPA-IHI) program that aimed to develop a QI tool using registry data and assess the impact of the QI tool with the same registry. Using LOS and readmission after elective lumbar fusion as target outcomes in this pilot module, we describe our preliminary experience examining how registries can bridge the gap between data collection and applied QI.

Methods

Study Design

A three-pronged, prospective cohort study was undertaken. 1) The Research Phase included an in-depth review of the literature and preexisting QOD registry data (October–December 2016). 2) The Development Phase consisted of meetings among NPA-IHI leaders to develop a QI tool (January–March 2017). 3) The Implementation Phase was a prospective cohort study that assessed the intervention of the QI tool using the existing registry to monitor outcomes (April–June 2017). Each phase facilitated the broader goal of using a registry to collect and analyze outcomes data, define an opportunity, deploy an intervention, identify new drivers of care, and refine the QI intervention (Fig. 1). Eight centers participated in the prospective arm and provided their respective IRB approval.

Partnership

The NPA is a nonprofit organization that coordinates the acquisition, analysis, and reporting of clinical data from neurosurgical practice using online technologies. In 2016, the NPA partnered with the IHI, an international leader in healthcare quality improvement based in Cambridge, Massachusetts. The objective of the NPA-IHI program was to derive insights from the QOD registry combined with IHI-validated QI methods to evaluate the impact of an applied QI tool.

Patient Population

Patients prospectively studied in phase 3 were drawn from 8 centers that comprise the Spine Surgery Learning Community (SSLC): Atlantic NeuroSurgical Specialists; Carolina Neurosurgery & Spine Associates; Goodman Campbell Brain and Spine; Norton Leatherman Spine Center; Semmes-Murphey Neurologic and Spine Institute; University of California, San Francisco; University of Utah; and Vanderbilt University. All centers were preexisting members of the larger QOD. Since its inception in 2012, the QOD Spine Registry is a continuous, national registry that monitors spinal surgical care and provides surgeons and hospitals with an infrastructure for analyzing and reporting the quality of their care. The QOD has enlisted a large population of patients undergoing lumbar spine surgery from 110 participating centers across 36 US states. Major conclusions from the registry have been reported elsewhere.

Patients undergoing elective, 1- to 3-level lumbar spine fusion with the following diagnoses were included: stenosis, spondylolisthesis, primary or revision disc herniation, symptomatic mechanical disc collapse, and adjacent-seg-
ment disease. Exclusion criteria included age < 18 years, deformity (scoliosis > 20°), and fusion or surgical approach ≥ 4 levels. Additionally, patients with a history of spinal infection, tumor, trauma, or neurological paralysis were excluded.

Outcomes
Throughout all three phases, the two primary outcomes were 1) length of stay (LOS) and 2) readmission. LOS was analyzed as a continuous variable in hours to increase sensitivity, in keeping with prior reports. Readmission was binary and operationally defined as any unplanned readmission within 90 days of surgery. Both outcomes were chosen due to their significant impact on health systems, ease of data collection, perceived alignment with emerging bundled payment models, and the concept that variation in these outcomes reflected on a fragmented health-care delivery system. The existing registry that provided initial data for the project’s aim was the same registry used to monitor outcomes.

Research Phase
The Research Phase lasted 90 days (October–December 2016) and included an in-depth review of the literature and existing QOD data. The existing QOD registry was used to generate supplemental data on LOS and readmission after elective lumbar fusion. Additional topics of the literature review included risk factors for extended LOS and readmission, preoperative goal setting, medical optimization, standardized inpatient care protocols, enhanced recovery programs, multimodal pain management, and postdischarge follow-up. In addition to primary registry data, prior QOD studies assessing LOS and readmission were searched. IHI resources were also queried for tips on reducing readmission and extended LOS.

Development Phase
The Development Phase lasted 90 days (January–March 2017). Armed with data from literature and QOD review, NPA-IHI leaders met monthly to design a novel QI tool to mitigate the primary drivers of LOS and readmission. A key activity here was to describe specific components of the QI tool. Cooperative, multidisciplinary care teams (surgeons, nurses, midlevel providers, and clinic staff) worked together to transition from early, descriptive theories about how proposed change concepts could be transformed into actionable items able to be implemented and tested. A Driver Diagram was developed to visualize ideas for change and their relationship to one another as they relate to LOS and readmission. The final 15–30 days were spent collating the implementable QI tool to be deployed in the next phase.

Implementation Phase
The Implementation Phase lasted 90 days (April–June 2017) where the NPA-IHI engaged the 8 SSLC centers to test the proposed QI tool. Each center’s existing registry was used to monitor outcomes after the QI tool was implemented. Simultaneous with the implemented QI tool, a learning system was created that included several activities: weekly data submission, coaching calls, an email list-serv for virtual discussion, and monthly site calls. Overall, these processes were all part of the continuous model of “Plan, Do, Study, Act,” where the QI tool underwent constant testing and adaptation through discussion between NPA, IHI, and SSLC centers. New data were continuously analyzed with the hopes of improving the major areas that prevented discharge and/or influenced readmission.

Statistical Analysis
All continuous data are presented as mean (SD) and/or median and IQR, whereas all count data are presented as number (%). The assessment of preoperative discharge questions was measured as asked or not (binary) along with discharge readiness on a 0–10 scale (0 not ready; 10 completely ready). Satisfaction was measured on a 0–10 scale (0 not satisfied; 10 completely satisfied). Nonparametric tests were used to compare outcomes before and
Results

Research Phase

Results of the literature review and existing QOD registry analysis revealed valuable conclusions that informed the next phase. Previous QOD data had identified the following factors predictive of nonroutine discharges and extended LOS in an elective spine population: older age, higher BMI, and presence of depression. Medical readmission was shown to be associated with older age, male sex, diabetes, higher American Society of Anesthesiologists (ASA) grade, more fusion levels, unemployment, and higher baseline Oswestry Disability Index (ODI) scores. Surgical readmission was associated with similar factors of higher BMI, higher ASA class, more fusion levels, and higher baseline ODI, but new factors of female sex and depression were noted. Additional non-QOD literature showed that drivers of readmission and LOS were being underweight, decreased functional status, female sex, pulmonary disease, increased ASA class, and malnutrition. QOD data were also used to assemble a risk score to predict extended LOS and readmission with the following 6 factors: ASA class > III, age ≥ 70 years, ODI ≥ 70, diabetes, nonindependent ambulation, and nonprivate insurance.

Summarizing key themes drawn from a subset of the existing QOD registry, pain control and medical comorbidity management emerged as the key drivers of both outcomes. Additional QOD data showed that approximately 80% of readmissions occurred within the first 4 weeks, and 46% within 14 days. Temporal trends of readmission included: pain and early wound issues (week 1), medical complications (week 2), and surgical site infections (weeks 3–4).

Development

In the early steps of creating the QI tool, a driver diagram was formulated that conceptualized ideas aimed at reducing LOS and readmission (Fig. 2). Five primary drivers were identified, each with secondary drivers. Since not all areas could be tackled at once, two primary drivers (P3/P4 in Fig. 2) were chosen: 1) Discharge Planning and Care Transitions and 2) Patient Activation and Education.

Discharge Planning and Care Transitions

Discharge Planning and Care Transitions included early development of a preoperative discharge plan, enhanced communication between caregivers during the hospital stay, and postdischarge follow-up processes.

FIG. 2. Driver diagram to reduce LOS and readmission. d/c = discharge. Figure is available in color online only.
Patient Activation and Education

Patient Activation and Education included reducing presurgical risk factors (smoking, weight loss, and pain management) and clear expectation setting regarding inpatient and postdischarge care. NPA-IHI leaders conceptualized these efforts across the entire spectrum of care from preoperative visits to postacute care. Three specific areas of intervention were formulated that make up the QI tool: 1) preoperative discharge assessment, 2) inpatient activities, and 3) postdischarge calls (Fig. 3). The specific LOS Rounding Checklist is provided in Appendix 1. It is important to note that the QI tool may look a certain way at the study’s outset but will likely change during the continual refinement process. The QI tool presented is a more final version and underwent changes as the study evolved (Fig. 3). The QI tool does not represent a static entity but rather a dynamic one that can be changed as data are gathered. One such example of how data were used to refine the QI tool involved repurposing two of the participating clinical registries to prospectively collect data related to the predominant factors preventing discharge. Although a full account of that process is beyond the scope of the present analysis, in brief, individuals undergoing the index procedures were tracked from the time of surgery to discharge and specific reasons preventing discharge were recorded at multiple time points. On postoperative days 1 and 2, pain control, mobility, and indwelling devices were the primary issues preventing discharge. On postoperative day 3 and beyond, active medical problems and unresolved discharge plan issues predominated. This information greatly facilitated the creation of informed and focused interventions at various stages in patients’ treatment courses and is a practical illustration of how prospective data collection focused on outcomes (clinical and process) can continuously inform and enhance concurrent quality and care efforts.

Implementation

A total of 209 patients underwent elective, 1- to 3-level lumbar fusion during the study period (Table 1). The most common procedure was a standard posterior laminectomy and fusion without interbody (60.3%). The median LOS was 85.5 hours (3.2 days). The mean LOS was signifi-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>209</td>
</tr>
<tr>
<td>No. of levels fused, mean (SD)</td>
<td>1.4 (0.6)</td>
</tr>
<tr>
<td>1, n (%)</td>
<td>137 (65.6)</td>
</tr>
<tr>
<td>2, n (%)</td>
<td>58 (27.8)</td>
</tr>
<tr>
<td>3, n (%)</td>
<td>14 (16.7)</td>
</tr>
<tr>
<td>Operation, n (%)</td>
<td>126 (60.3)</td>
</tr>
<tr>
<td>Posterior laminectomy &amp; fusion</td>
<td>12 (5.7)</td>
</tr>
<tr>
<td>TLIF</td>
<td>2 (1.0)</td>
</tr>
<tr>
<td>MIS-TLIF</td>
<td>6 (2.9)</td>
</tr>
<tr>
<td>ALIF</td>
<td>63 (30.1)</td>
</tr>
<tr>
<td>Not recorded</td>
<td></td>
</tr>
<tr>
<td>LOS, hrs</td>
<td>85.5 (51.7)</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>76 (51–103)</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>7 (3.3)</td>
</tr>
</tbody>
</table>

ALIF = anterior lumbar interbody fusion; MIS = minimally invasive; TLIF = transformaminal lumbar interbody fusion.
significantly less for 1-level fusions (77.0 hours) compared with 2-level (99.8 hours) and 3-level (109.6 hours) fusions (p = 0.003) (Fig. 4). Six outliers (2.9%) with LOS > 200 hours were noted. Seven patients (3.3%) were readmitted during the study period. LOS did not differ significantly between the surgical procedures of posterior laminectomy and fusion, transforaminal lumbar interbody fusion, minimally invasive transforaminal lumbar interbody fusion, and anterior lumbar interbody fusion (p = 0.096).

Preoperative Discharge Planning

Five questions about discharge were asked in the preoperative setting, and 129 patients (61.7%) had all 5 preoperative questions asked (Table 2). A shorter median LOS was seen in patients who reported that they had a known preoperative discharge date (67 vs 80 hours, p = 0.018) and received clear discharge plan instructions (71 vs 81 hours, p = 0.030) (Fig. 5A and B). With regard to patient satisfaction (measured on a scale from 0 to 10), patients reporting they had a known preoperative discharge plan reported significantly increased patient satisfaction (8.0 vs 7.0, p = 0.028) and patients with increased discharge readiness (measured on a scale from 0 to 10) also reported higher satisfaction (r = 0.474, p < 0.001) (Fig. 5C), supporting the driver diagram theory that better discharge readiness will positively influence the patient experience.

Postdischarge Calls

A total of 159 patients (76.1%) were contacted within 2–5 days of discharge to assess pain, healing, and primary care follow-up with the hope of intervening early enough to prevent an emergency department visit or readmission. Interestingly, those who received postdischarge calls had a significantly shorter LOS than those who did not (75 hours vs 99 hours, p = 0.020) (Fig. 6). However, no significant relationship was seen between postdischarge calls and readmission (p = 0.342), likely due to the small number of readmissions. Postdischarge calls were also a rich source of qualitative data. Centers reported anecdotal improvement in the following areas: improved patient experience, prevention of emergency department visits, and greater knowledge and proactivity in addressing preoperative educational needs. At the study’s conclusion, site-level summaries were provided for specific feedback and improvement.

**Discussion**

Through three phases consisting of research, development, and implementation, the NPA-IHI pilot program successfully used registry data to create and implement a novel QI tool to decrease LOS and readmission after elective lumbar fusion. Preoperative discharge planning that identified an established date of discharge and formulated clear discharge instructions was associated with a shorter LOS, and overall discharge readiness led to higher patient satisfaction. Postdischarge calls were also associated with decreased LOS but not decreased readmission. The current NPA-IHI program offers several noteworthy lessons in applied QI and highlights how registries can be used to begin the QI process and in turn collect outcomes data on a proposed intervention.

**TABLE 2. Preoperative, inpatient, and postoperative discharge activities**

<table>
<thead>
<tr>
<th>Preop &amp; inpatient discharge activities</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Were all 5 discharge assessment questions asked? (n = 209)</td>
<td>129 (61.7)</td>
</tr>
<tr>
<td>Did a discharge plan exist? (n = 193)</td>
<td>133 (68.9)</td>
</tr>
<tr>
<td>Was there a date? (n = 151)</td>
<td>127 (84.1)</td>
</tr>
<tr>
<td>Was there a location? (n = 149)</td>
<td>132 (88.6)</td>
</tr>
<tr>
<td>Were instructions clear? (n = 158)</td>
<td>142 (89.9)</td>
</tr>
<tr>
<td>Discharge readiness while inpatient (n = 131)*</td>
<td>-</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>8.8 (1.9)</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>10 (8–10)</td>
</tr>
</tbody>
</table>

**Postop discharge activities**

| Postdischarge call made (n = 209) | 159 (76.1) |
| Patient satisfied? (n = 123)† | - |
| Mean (SD) | 7.7 (2.2) |
| Median (IQR) | 7 (7–10) |

**Patient satisfaction, n (%) (n = 132)**

| Exceeded expectations | 51 (38.6) |
| Satisfied | 70 (53.0) |
| Not satisfied | 3 (2.2) |
| Did not meet expectations | 4 (3.0) |
| Unsure | 4 (3.0) |

Values represent the number of patients (%) unless stated otherwise.

* 0 = not ready; 10 = completely ready.
† 0 = not satisfied; 10 = completely satisfied.
much rarer are intervention studies assessing the impact of preoperative patient counseling. Louw and colleagues prospectively randomized 67 patients undergoing lumbar spine surgery to a neuroscience education class (e.g., nervous system physiology, surgical experience, surgical recovery) versus control and showed that the education group felt better prepared for surgery, reported more often that surgery met their expectations, and had 45% less healthcare expenditures at 1 year. A similar retrospective study by Eastwood et al. reported that a 2-hour preoperative seminar on surgery preparation and proper postoperative care given to 103 patients undergoing lumbar fusion was associated with reduced emergency department utilization, greater satisfaction, and improved postoperative back pain compared with those who did not attend the seminar. These results, and others, confirm that proactive, preoperative planning can improve the hospital experience and outcomes.

One interesting finding was that postdischarge calls were associated with a decreased LOS. While this is somewhat counterintuitive given that calls were made after the hospitalization was over, it is feasible that if patients know they are going to receive a call from their provider soon after discharge, they are more likely to leave the hospital sooner. Knowledge of an incoming call may put patients at ease and provide comfort knowing that if any issues arise, their providers are close by and willing to help. In a series of patients undergoing elective cranial (40.6%) or spinal surgery (59.4%), Robertson and colleagues administered a transitional care program in 416 patients that included in-hospital prescription filling, a postdischarge call at 2 days, and education on postoperative activity. The transitional care program was associated with decreased LOS (62.1 hours vs 79.6 hours, p < 0.001), increased morning discharges (p < 0.001), and decreased 30-day readmission (p = 0.02). In a prospective, randomized trial of patients undergoing elective orthopedic surgery, Clari et al. similarly showed that nursing-led phone calls on postdischarge day 2 were associated with decreased problems with medication management, routine self-care, and prescribed exercises.

Despite the promising preliminary results, the greatest takeaway from the NPA-IHI program is the process of improvement, which is unfamiliar territory compared with the more routine process of data collection and analysis. First, the learning community was designed to test a theory of change and not bring about immediate research-grade results, which is incongruent with the usual lens of the outcomes researcher. Oftentimes, surgeons at SSLC centers approached the QI work with a research focus.
and sourced the project only to their research coordinators, rather than to a multidisciplinary team involved in patient care. This was rectified by bringing together all stakeholders (clinic staff, clinic nurses, inpatient nurses, and data coordinators) to work toward the common goal of QI. Second, documentation of preoperative discharge planning and postdischarge calls were at first collected in a separate database disconnected from the electronic medical record (EMR). As data collection ensued, centers encountered difficulty with the added work of collecting this information in a separate platform. From this experience, embedding the preoperative discharge planning and postdischarge calls directly into the EMR proved vital to successful implementation at many centers. This approach built sustainability into the process and allowed the use of nonclinical professionals to conduct postdischarge calls. Any concerning information was flagged to a surgical nurse. Third, the creation of a care navigator was particularly useful at select sites. The navigator was often a nurse or midlevel provider and would ensure that patients were following orders before surgery, communicate with primary care providers, address patient concerns, and confirm that the patient understood the recovery process. Fourth, given the low number of readmissions and small variability in LOS, reliance on qualitative data became important. Not relying on concrete data conflicts with the evidence-based approach we are conditioned to abide by, but with the nuances of applied QI, reliance on anecdotal information from the clinical team is important to know what works, what needs refining, and what new directions to pursue.

Using the NPI-IHI collaboration as a platform for future QI work, one potential new direction is to look at the operations. As it stands, there are more than 20 different surgical techniques to treat mobile grade 1 spondylolisthesis. Equally important as patient education and discharge counseling is the surgical approach and operative technique performed. The same rigor applied to the current project can be transferred to the operating room environment, where data coordinators collect specific, detailed information about each step of the surgical procedure (e.g., time, sequence, equipment, and assistants) from induction to closure. These surgery-specific data points can then be correlated with patient outcomes, and operative technique can be adjusted and revised accordingly.

The current study is not without limitations. First, the rapid intervention of a QI tool and prospective nature of the study led to missing data. Several areas had missing data, and the QI tool was not universally implemented at all centers. These gaps in care were reported and are unfortunately inherent to any intervention study. Equally unfortunate was that data on the 7 readmitted patients were not entered into the registry, which prevented further study of this important group of patients. Similarly, 30% of patients did not have a surgical procedure recorded. Despite being recorded in each institution’s EMR, the data were not translated to the registry, although analogously, the majority of these were posterior laminectomy and fusions. Second, our statistical analysis was hindered by these missing data, and we caution against overinterpretation of the data. Third, as the study continued, areas in need of improvement were identified that varied between centers. Securing extra nursing resources for preoperative and postdischarge calls was a common concern, where some centers were much better equipped to implement the QI tool and collect data than others. Fourth, gaining buy-in from all surgeons within a practice was also difficult, as some providers preferred to take a reactive approach and only call patients if patients first reached out to them. Fifth, several patients were unable to be contacted after discharge. We found that contacting patients postdischarge was easier when the patient went home but harder when they were transferred to a facility. Lastly, 3-level fusions were grouped in with 1- and 2-level fusions and represent significantly larger operations. However, despite the increased heterogeneity, 3-level fusions widened the LOS window, thus allowing for more change and variation to be seen after QI tool implementation.

Overall, the current NPA-IHI collaboration reported promising results combining insights from a national registry with applied QI that utilized the existing registry to assess change. The process of applied QI is essential to maximize the use of our robust clinical registries, and we imagine creation of scalable applied QI tool kits for national QI implementation that serve as a clear guide of how to create applied QI programs. Each tool kit would mimic the process outlined here to identify outcomes of interest, conduct a background literature and registry search, develop a QI tool, and implement the proposed QI tool with the existing registry. The process can be easily repeatable from start to finish, customized to meet each institution’s need.

Conclusions

The results of our NPA-IHI collaboration to reduce LOS and readmission after elective lumbar spine surgery showed that preoperative discharge planning and postdischarge calls have the potential to reduce LOS and improve satisfaction. Several themes for applied QI were realized that serve as a clear guide of how to create applied QI programs. Each tool kit would mimic the process outlined here to identify outcomes of interest, conduct a background literature and registry search, develop a QI tool, and implement the proposed QI tool with the existing registry. The process can be easily repeatable from start to finish, customized to meet each institution’s need.
QI implementation as a distinct process from data collection and analysis and use registries to assess the impact of QI initiatives within their own practices.

Acknowledgments

We acknowledge the following people who were instrumental in completing this work: Anila Hussaini, RN, MPH; Sue Butts-Dion; Kevin Little, PhD; Linson Naval; Michele Anderson; Sarah Hendrix; and Cameron Johnson.

References

Disclosures
This study was supported through a grant from the Neurosurgery Research & Education Foundation (NREF).
Dr. Devin: consultant for Stryker Spine and direct stock ownership in Balanced Back. Dr. Knightly: personal relationship with NPA. Dr. Potts: consultant for and royalties from Medtronic. Dr. Foley: consultant for Medtronic; direct stock ownership in Discgenics, DuraStat, LaunchPad Medical, Medtronic, NuVasive, Practical Navigation/Fusion Robotics, True Digital Surgery, Tissue Differentiation Intelligence, and Triad Life Sciences; patent holder with Medtronic and NuVasive; royalties from Medtronic; and board of directors of Discgenics, DuraStat, LaunchPad Medical, Practical Navigation/Fusion Robotics, Tissue Differentiation Intelligence, and Triad Life Sciences. Dr. Bisson: consultant for MiRus and Stryker. Dr. Glassman: employee of Norton Healthcare; consultant for Medtronic and K2M/Stryker; royalties from Medtronic; patent holder with Medtronic; clinical or research support from the study described from NuVasive, Integra, Intellirod, Norton Healthcare, Pfizer, and International Spine Study Group (ISSG); editor at Springer; and nonfinancial relationship with SRS (past president) and American Spine Registry (chair). Dr. Mummaneni: consultant for DePuy Synthes, Globus, and Stryker; direct stock ownership in Spinicity/ISD; royalties from DePuy Synthes, Springer Publishing, and Thieme Publishing; clinical or research support for this study from NREF; and support of non–study-related clinical or research effort from ISSG and AO Spine.

Author Contributions
Conception and design: Asher, Devin, Knightly, Potts, Foley, Bisson, Glassman, Mummaneni, Bydon. Acquisition of data: Rossi, Bydon. Analysis and interpretation of data: Zuckerman, Chotai, Dyer. Drafting the article: Zuckerman. Critically revising the article: Asher, Zuckerman, Devin, Rossi, Chotai, Dyer, Knightly, Potts, Foley, Bisson, Glassman, Bydon. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Asher. Statistical analysis: Zuckerman. Administrative/technical/material support: Asher, Zuckerman, Bydon. Study supervision: Asher, Devin, Dyer, Knightly, Potts, Foley, Bisson, Glassman, Mummaneni, Bydon.

Supplemental Information
Online-Only Content
Supplemental material is available with the online version of the article.

Previous Presentations
Portions of this work were presented at the 86th AANS Annual Scientific Meeting, New Orleans, Louisiana, April 30, 2018.

Correspondence