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# Improving care through standardized treatment of spontaneous pneumothorax☆

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ABSTRACT

*Purpose:* The objective of this quality improvement (QI) initiative was to implement a standardized clinical treatment protocol for patients presenting with primary spontaneous pneumothorax (PSP) in order to decrease hospital length of stay (LOS), diagnostic radiation exposure, and related cost.
*Methods:* Baseline data from patients admitted with PSP from January 1, 2016 to July 31, 2018 were compared to data from patients managed using a newly developed evidence-based treatment pathway from August 1, 2018 to December 31, 2019. Standard QI methodology was used to track results.
*Results:* Fifty-six episodes of PSP were observed during the baseline period and 40 episodes of PSP following initiation of the PSP protocol. The average LOS decreased from 4.5 days to 2.9 days. Patients underwent an average of 8.8 X-rays per admission preintervention versus 5.9 postintervention. The rate of CT scans decreased from 45% to 15% ($p = 0.002$). There was no significant difference in the rates of 30-day recurrence between the preintervention (13%) and postintervention (10%) groups ($p = 0.7$). Average admission costs per patient decreased by $1322 after adoption of the pathway.
*Conclusions:* Adoption of a standardized treatment protocol for PSP led to a reduction in LOS, diagnostic imaging utilization, and cost without increasing clinical recurrence.
*Type of study:* Quality improvement.
*Level of evidence:* Level III.



Primary spontaneous pneumothorax (PSP) is a relatively rare occurrence, with an estimated incidence of 7.4 to 18 cases per 100,000 male patients and 1.2 to 6 cases per 100,000 female patients [1]. While some guidelines have been set forth for the management of PSP, these have been by specialty societies that predominantly care for adult patients [2,3]. A recent literature review highlighting the lack of evidence in pediatric patients regarding related management decisions reveals a lack of consensus and standardized practice [4]. The paucity of clear guidelines regarding the treatment of pediatric PSP has resulted in clinical practice variation across surgical faculty at our institution. Therefore, we developed a clinical protocol based on recent literature regarding radiological imaging and intervention for PSP [4–7]. The primary objectives of such standardized care included reduction in hospital length of stay and radiation exposure related to diagnostic imaging.

## 1. Methods

A quality improvement (QI) project designed to address the management of pediatric patients with PSP was developed. Per institutional protocol, QI projects are not considered human subjects research, obviating a requirement for institutional review board approval. Baseline data were obtained for all patients older than 11 years of age admitted to Nationwide Children's Hospital from January 1, 2016 to July 31, 2018 with a diagnosis code of primary spontaneous pneumothorax (ICD-9 CM: 512.0, 512.81, 512.83, 512.84, 512.89; ICD-10 CM: J93.0, J93.11, J93.8, J93.81, J93.92, J93.9). The QI cohort consisted of PSP patients managed with the newly developed clinical protocol (August 1, 2018 to December 31, 2019). Patients with traumatic pneumothorax, connective tissue disease, or other underlying pulmonary conditions were excluded. Patients were also excluded if their hospital stay for

☆ *How this paper will improve care: This quality improvement project in a tertiary children's hospital demonstrates that standardization of care of primary spontaneous pneumothoraces, guided by radiological parameters in conjunction with the number of previous episodes, reduces hospital length of stay and diagnostic radiation exposure.*

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PSP was complicated/prolonged by a medical problem not related to their PSP diagnosis or treatment, and/or participation in the Midwest Pediatric Surgery Consortium prospective trial of percutaneous aspiration treatment for PSP ($n = 9$) [7]. PSP patients initially managed with observation only, as well as those who underwent related procedural intervention (i.e. pigtail placement, chest tube placement, and/or video-assisted thoracoscopic surgery (VATS)), were included in the analysis. Corresponding data for the patients in the baseline cohort were compared to those in the QI cohort.

A key driver diagram was constructed; interventions included the development of a clinical protocol for management of PSP based on the number of patient episodes, as well as education of faculty and staff regarding the protocol, with detailed instructions on specific components of care such as pneumothorax aspiration. Patient records were reviewed quarterly to assess our process measure of compliance with the protocol. Outcomes measured included hospital length of stay (LOS) and number of radiological imaging procedures (X-ray, computed tomography (CT)) performed. Hospital LOS was calculated from time of admission (from emergency department) to time of discharge recorded in the patient's electronic medical record. The balancing measure for the clinical protocol was PSP recurrence within 30 days of discharge from the previous episode. Recurrence was defined as subsequent documentation of an ipsilateral PSP. The initial aim of the project was to decrease the average LOS from 4.5 days at baseline to 3.5 days and sustain for one year.

### *1.1. Protocol for the management of pediatric primary spontaneous pneumothorax*

An evidence-based clinical protocol was developed with stratification based on the number of previous episodes of PSP in order to standardize treatment (Fig. 1). Patients presenting with no prior history of PSP (i.e. first episode) were stratified by size of the pneumothorax and related symptoms. Patients presenting with a second episode could be treated with a conservative approach (per Episode 1) or elect to proceed with VATS according to patient/family and surgeon preference. For patients presenting with a third episode, the protocol recommended they forego conservative management in exchange for VATS, with placement of a pigtail catheter in the emergency department if deemed necessary based on size of the pneumothorax and/or patient symptoms. Additionally, guidelines for the subsequent timing of radiological imaging and detailed chest tube management, including troubleshooting

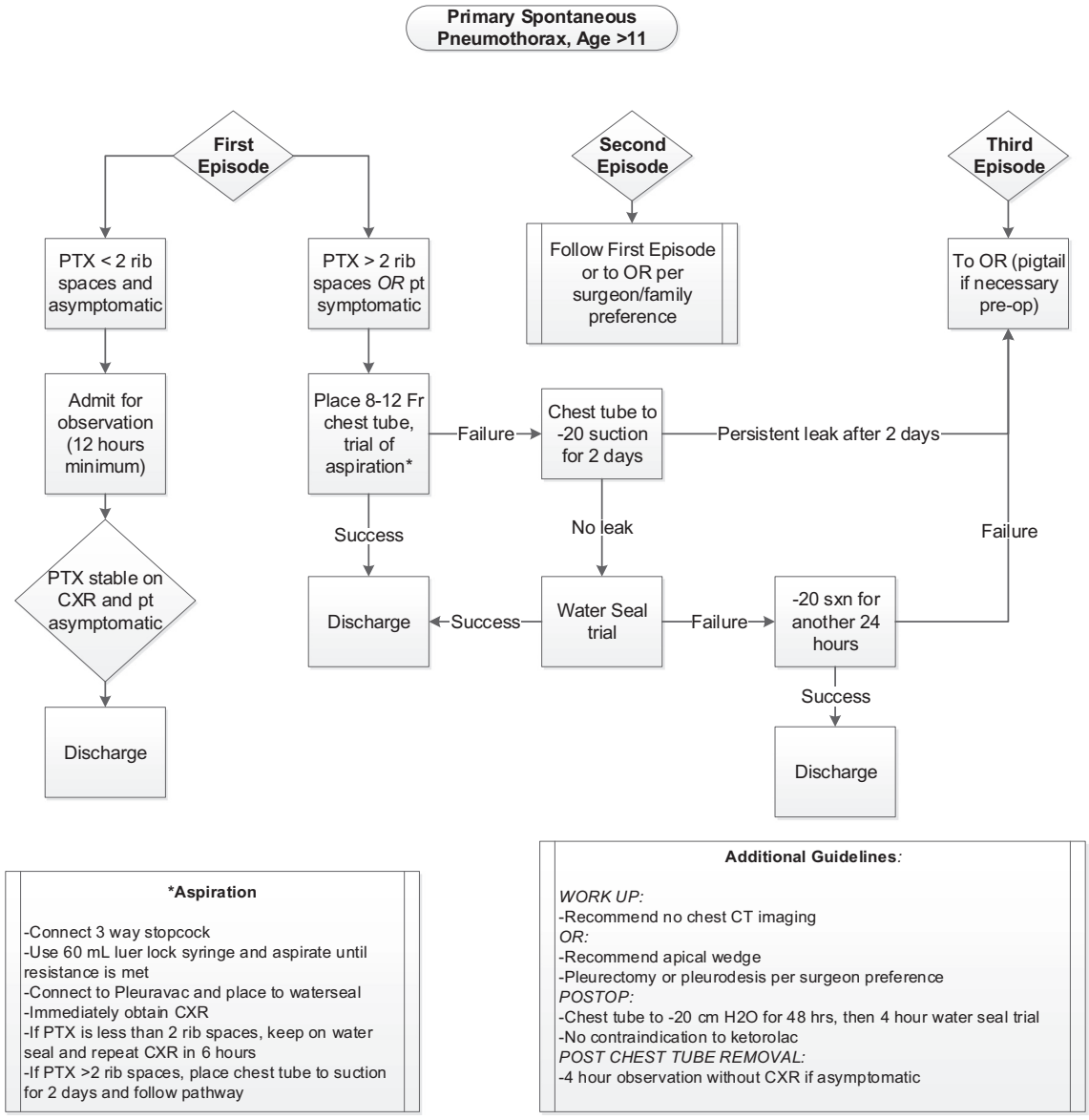


**Fig. 1.** Protocol for the management of patients who present with primary spontaneous pneumothorax (PSP).

considerations, were provided. Prior to initiation of the clinical pathway the proposed protocol was presented to the surgical faculty for feedback and modifications. Educational material (a pocket card summarizing the protocol) was distributed to all faculty, surgical nurse practitioners and surgical trainees, and the protocol was available on the clinical intranet for reference.

An initial trial of aspiration was recommended for patients in whom pigtail placement was the planned definitive management (during episode 1 or 2) per established guidelines [7]. Aspiration was not routinely performed at our institution prior to initiation of the pathway. Surgeons were instructed to place and secure a small (8–12 French) pigtail per standard procedure. A three-way stopcock was then connected to the end of the catheter. Using a syringe, the surgeon then manually aspirated air from the pleural cavity until s/he met resistance or briefly connected the suction tubing to suction. The pigtail was then connected to the atrium device and placed to water seal. A chest x-ray was immediately obtained, and if the pneumothorax was less than two rib spaces, the catheter remained on water seal and a repeat chest x-ray was performed in approximately six hours, with chest tube removal if the pneumothorax was stable. If at the time of aspiration, the chest x-ray showed that the pneumothorax was still greater than two rib spaces, the catheter was placed to suction for 48 h and the rest of the management proceeded per protocol guidelines.

### 1.2. Data analysis

A time-series experimental design was used to compare data starting with the baseline cohort in 2016. Data for LOS and average number of x-rays per admission were collected on a quarterly basis and analyzed using a Shewhart process control chart. The center line of these charts is based on the mean of the baseline and process stage, established with a minimum of six consecutive values. The upper and lower control limits are set at three standard deviations from the mean. If a point falls outside of the control limits it is considered special cause variation, whereas points within the control limits are considered common cause variation. [8] As per American Society for Quality guidelines, the signal for a shift in the baseline was based on having 10/11 points below the previous center line [9]. Statistical analysis was performed on the data monthly to identify special cause variation or a baseline shift. Categorical variables were compared using Chi-squared analyses. Average cost data were provided by the finance department at our institution. Compliance with the protocol was calculated per patient, and their treatment was deemed to be compliant with the pathway if all steps of the protocol were followed. Compliance for aspiration was calculated separately.

## 2. Results

Prior to initiation of the clincal protocol (i.e. baseline period) 45 patients had 56 occurrences of PSP. Following the protocol initiation 34 patients had 40 occurrences of PSP. The majority of patients were white, non-Hispanic males (Table 1). The median age at presentation was 16 years (IQR 1). Less than 10% of patients in both groups reported smoking or vaping. Approximately one-third of patients in both groups had previously experienced a PSP on the side of current presentation (preintervention 39%; postintervention 28%; p = .23; Table 1). Approximately 10% of patients in both groups had experienced more than one PSP on the side of current presentation (preintervention 13%; postintervention 10%; p = .7). Eleven percent of patients in the preintervention group and 13% in the postintervention group had a history of contralateral PSP (p = .9).

Of patients admitted to the hospital with a PSP, 29% in the preintervention group (i.e. prior to initiation of the PSP protocol) and 23% in the postintervention group (i.e. following initiation of the PSP protocol) did not undergo any type of surgical procedure during their hospital stay (Table 2). Forty-six percent of patients in the preintervention group and 40% of patients in the postintervention group underwent VATS with pulmonary wedge resection and pleurectomy or pleurodesis.

**Table 1**
Demographics and patient characteristics.

| | Preintervention ($n = 45$) | Postintervention ($n = 34$) | *P* |
|---|---|---|---|
| Age (median (Q1–Q3)) | 16 (15–17) | 16 (15–17) | 1.0 |
| *Sex* (%) | | | |
| Male | 82% | 88% | .5 |
| Female | 18% | 12% | |
| *Race* (%) | | | |
| White | 78% | 85% | .4 |
| Black | 11% | 6% | |
| Asian | 7% | 9% | |
| More than one race | 2% | 0% | |
| *Ethnicity* (%) | | | |
| Hispanic | 4% | 6% | .8 |
| Non-Hispanic | 98% | 94% | |
| Smoker (%) | 7% | 6% | .9 |
| *PSP history (n = 56, 40)* (%) | | | |
| Previous ipsilateral PSP | 39% | 28% | 0.23 |
| More than one previous ipsilateral PSP | 13% | 10% | 0.7 |
| History of contralateral PSP | 11% | 13% | 0.9 |

PSP, primary spontaneous pneumothorax.

Baseline average LOS was 4.5 days. After initiation of the PSP protocol, there was a shift in the center line to an average LOS of 2.9 days (Fig. 2). Our baseline average number of x-rays per hospital stay was 8.8. This shifted to an average of 5.9 x-rays per hospital stay after initiation of the PSP protocol (Fig. 3). Additionally, prior to the intervention 45% of patients had a CT scan as part of their workup, and after the intervention only 15% did (p = .002). Of patients who had a tube thoracostomy performed at our institution ($n = 21$) only 57% had aspiration performed per the protocol recommendations. Compliance with the protocol was initially 100%, but this decreased during the third and fourth quarter of 2019 (Fig. 4). There was no significant difference in the rate of overall recurrence (27% in preintervention versus 17.5% in postintervention; p = 0.1) or in recurrence within 30 days of discharge (preintervention 13%; postintervention 10%; p = 0.7).

The average overall cost per admission during the preintervention period was $8303 (with $4353 owing to radiology costs). The average overall cost in the postintervention period was $6981 (with $3120 owing to radiology costs). The overall decrease in cost per admission was $1322, of which $1233 was because of a decrease in radiology costs.

## 3. Discussion

This quality improvement project of a standardized protocol to treat patients presenting with a spontaneous pneumothorax demonstrates a shift in the baseline LOS of greater than one day as well as a reduction in radiation exposure and decreased cost without an increase in recur-

**Table 2**
PSP management and balancing measures.

| | Preintervention ($n = 56$) | Postintervention ($n = 40$) | *P* |
|---|---|---|---|
| CT scan performed | 45% | 15% | 0.002 |
| No intervention | 29% | 23% | 0.5 |
| To OR during admission | 46% | 40% | 0.5 |
| Recurrence | 27% | 17.5% | 0.1 |
| Recurrence within 30 days | 13% | 10% | 0.7 |

CT, computed tomography; OR, operating room.

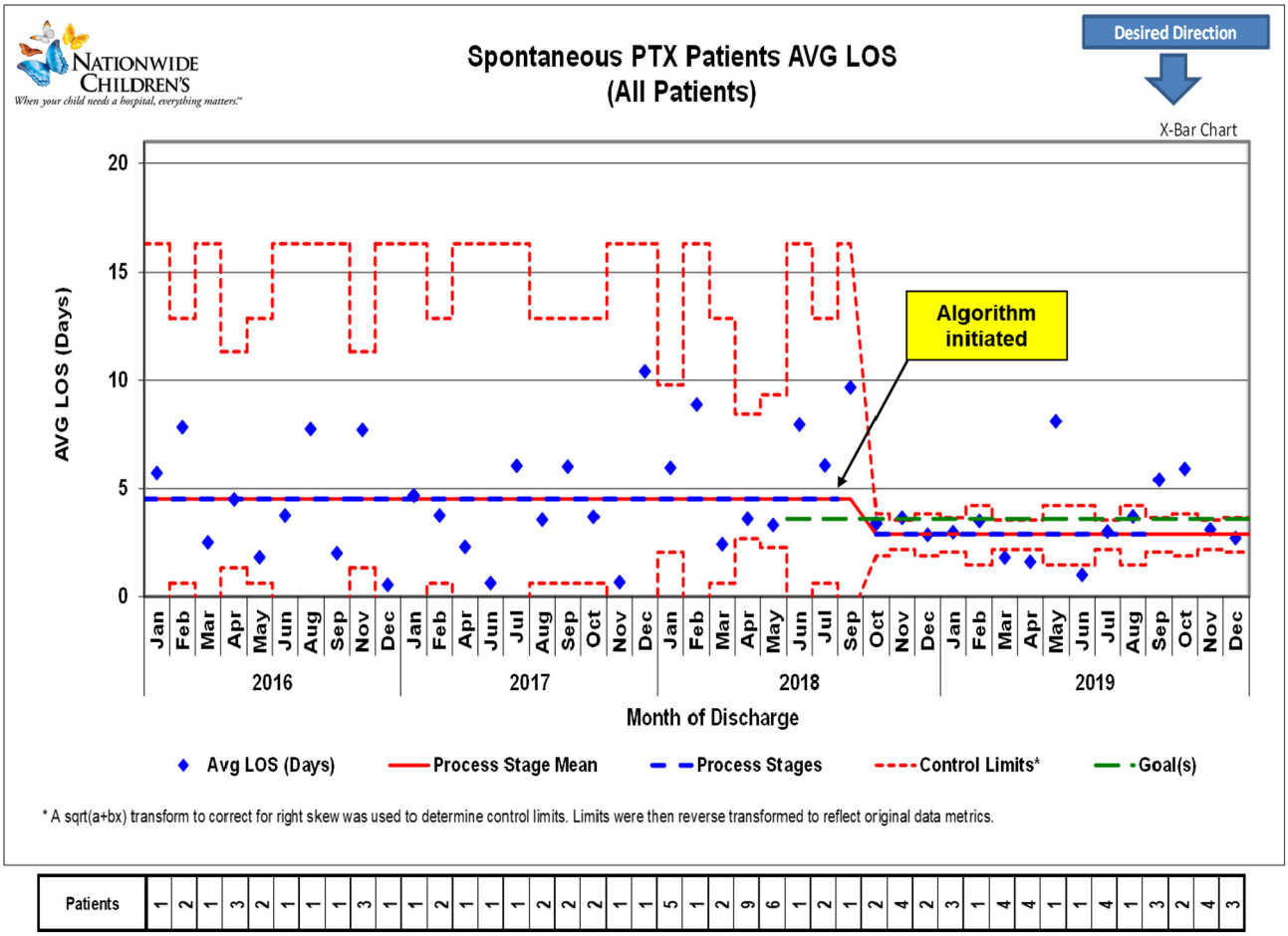


**Fig. 2.** Control chart for overall hospital length of stay (LOS).

rence rates. The management of PSP has been based on guidelines from the adult literature [2–4]. One of the primary interventions for large or symptomatic PSP in adults has been simple aspiration [2,3]. This technique has been described using either a large needle or a pigtail catheter. [2,3] A randomized trial in adults showed similar outcomes with regards to initial treatment, recurrence, and complications when comparing aspiration to tube thoracostomy in patients presenting with their first episode of PSP [10–12]. A recent study from the Midwest Pediatric Surgery Consortium examined the outcomes of pigtail catheter aspiration for the first episode of PSP in pediatric patients [7]. They found that aspiration using a pigtail catheter predicted chest tube failure with an 83% positive predictive value. Additionally, aspiration via catheter allows for a single intervention and, should the aspiration fail, the ability to place the tube to suction. We included aspiration in our protocol for first or second episode of PSP and recommended that failure of aspiration should lead to 48 h of monitoring. If the patient had a persistent air leak after 48 h, surgery was recommended.

Early surgery has recently been shown to be effective in management of PSP in recent retrospective studies. Lopez et al. found that 37% of 108 patients admitted with PSP ultimately required VATS during their hospitalization and nonoperative management resulted in significantly longer lengths of stay (11 days versus 5 days, $p < .001$) [13]. Williams et al. found that 50% of 46 patients admitted with PSP eventually underwent VATS and concluded that presence of an air leak or incomplete lung expansion within the first 48 h of admission should prompt surgical intervention as they were significant predictors of requiring VATS [14]. Soler et al. found that of 80 patients admitted with their first PSP, recurrence was significantly higher in patients who underwent nonoperative management compared to those who underwent VATS during their admission (45% versus 14%, $p = .04$) [15]. Our pre- and postintervention groups had similar rates of VATS during admission, but utilization of our protocol resulted in a downward shift in the baseline length of stay of approximately one and a half days, indicating that these changes are likely not because of rates of operative management, but may be related to timing and overall management. Results from the previous literature demonstrate that earlier definitive operative intervention may shorten hospital courses and possibly decrease rates of recurrence. Length of stay in the aforementioned studies ranged from 3.4 days in patients undergoing observation alone reported by Soler et al. to a median LOS of six days across all patients in the cohort observed by Williams et al. [15] We had a shift in our baseline LOS from 4.5 to 2.9 days, but after a year of using the protocol, we noticed some decrease in protocol compliance (Fig. 4) which was associated temporally with a few months of increased LOS indicated by several points outside of the control limits on our run chart. While we cannot assume causation, this correlation suggests that the protocol was effective and that it is important to continue to encourage compliance.

While most literature surrounding the care of spontaneous pneumothorax focuses on improving outcomes through various interventions, a recently published prospective randomized trial looked at patients 14–50 years of age who presented with a moderate to large spontaneous pneumothorax, and randomized patients to either observation alone or intervention with pigtail insertion without suction [16]. Eight-five percent of patients in the observation arm did not undergo any intervention for their pneumothorax. The authors found that patients who underwent observation alone had a noninferior rate of resolution of the pneumothorax when compared to patients who underwent an intervention (98.5% observation group; 94.4% intervention

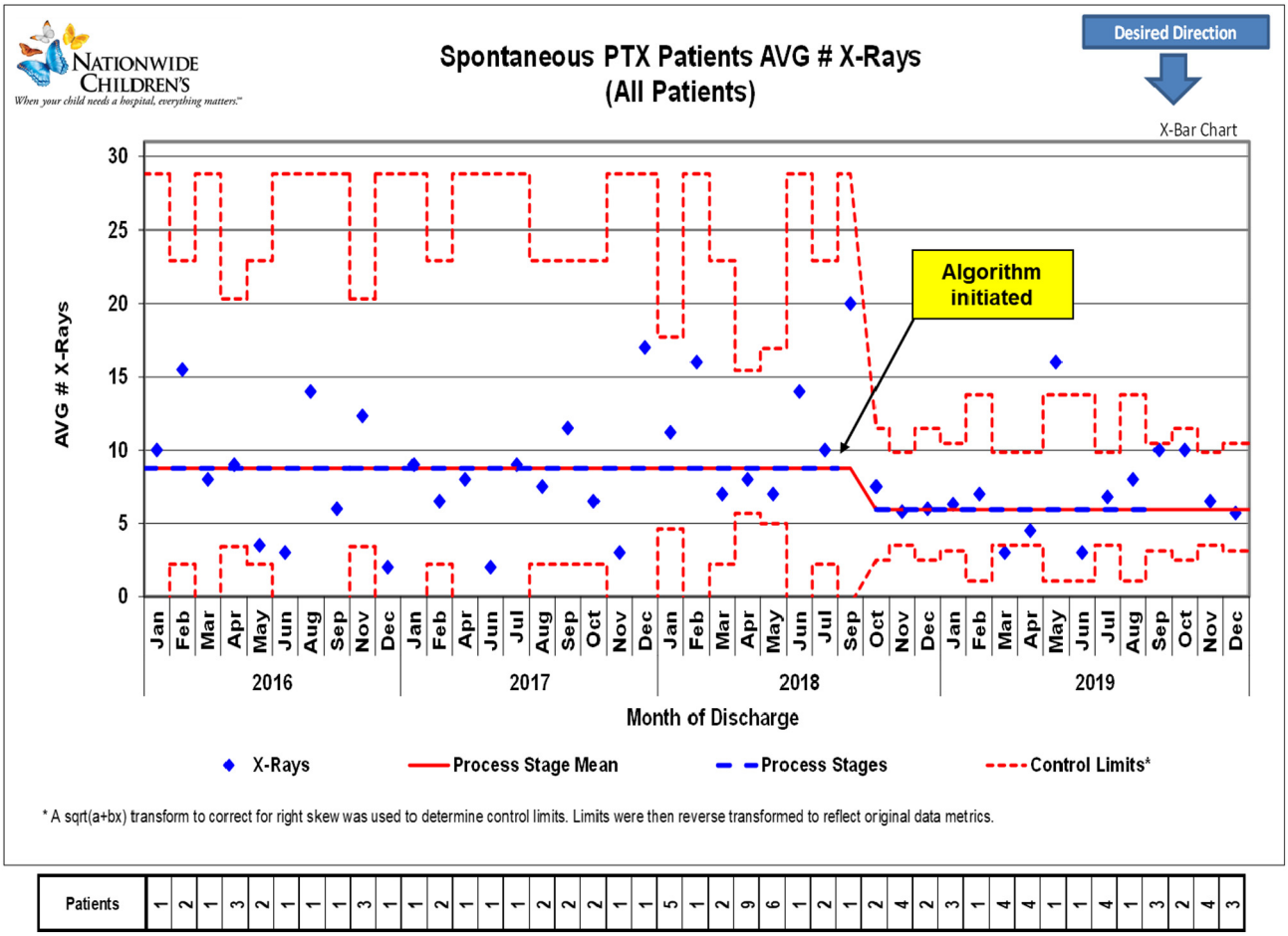


**Fig. 3.** Control chart for the average number of patient-associated X-rays per hospital admission.

group; risk difference, −4.1 percentage points; 95% confidence interval [CI], −8.6 to 0.5; P = 0.02 for noninferiority). Additionally, the investigators observed that patients in the observation group had a significantly lower rate of recurrence compared to those in the intervention group (8.8% vs. 16.8%, respectively; relative risk 1.90 (95% CI: 1.03–3.52)). Other studies have shown that aspiration may be a way to test whether

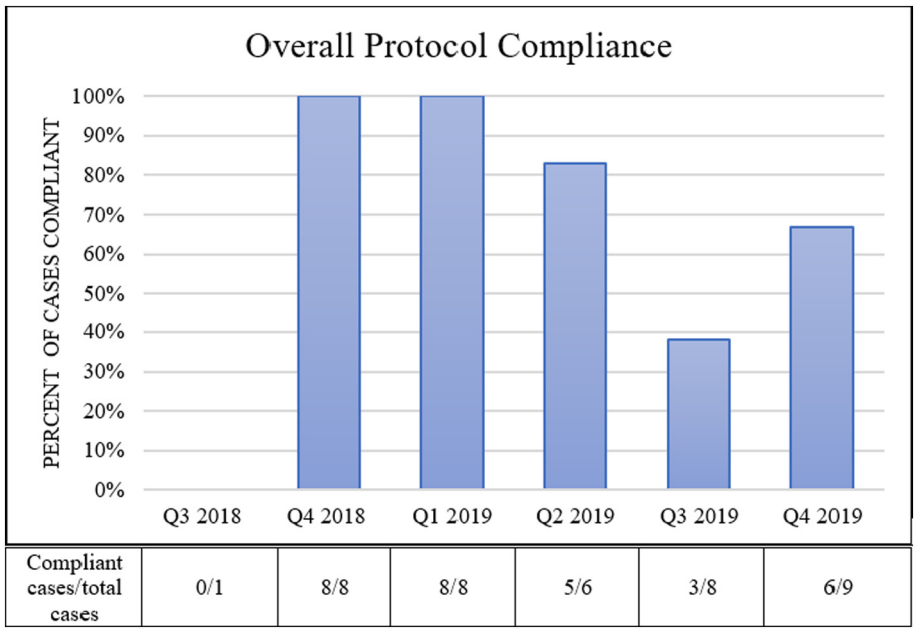


**Fig. 4.** Protocol compliance by quarter.

the patient's pneumothorax will resolve quickly, but the results from this recent trial indicate that many spontaneous pneumothoraxes will resolve without any intervention at all. However, while this study did include pediatric patients, it is likely prudent to perform a more focused trial of observation alone in pediatric patients to ensure that the results are replicated in the pediatric population, and that observation alone is a safe management option to offer to patients.

Another component to consider in the treatment of PSP is radiation exposure. While x-rays are an important part of the diagnosis and treatment of PSP, efforts should be made to minimize radiation exposure as long as quality of care is maintained. In our baseline cohort we found that that 45% of patients had a CT scan performed, presumably to evaluate for blebs. However, recent studies have shown that CT scans do not predict recurrence [6,15,17]. Laituri et al. looked at 26 patients who underwent CT scans and surgical management of their PSP and found that CTs had a sensitivity for identifying blebs at a rate of 36% and was only able to identify contralateral blebs that resulted in metachronous contralateral disease in 20% of patients. They concluded that surgical treatment should be based on clinical judgment, not CT findings [6]. In our protocol, we recommended against CT scan usage based on the results from the previously cited studies. We were able to decrease CT usage significantly to only 15% of patients. Surgeons reported that some CT scans were obtained owing to specific circumstances, such as patients who had pneumothorax recurrence after undergoing VATS, or to identify contralateral blebs in patients with high-risk career plans such as aviation. While there may be room for improvement in the rate of CT scans performed, our pathway does not account for every possible scenario, so it is likely that some CT scans will continue to be performed for unanticipated scenarios.

Additionally, we sought to decrease x-ray usage. Cunningham et al. compared patients at a single institution who had routine chest x-ray after chest tube removal to patients who had their chest tube removed with no immediate follow up imaging. They found that reinsertion was rare and was based on symptoms, not imaging findings, and recommended against routine postremoval x-ray [5]. We included this recommendation in our protocol as well, and also recommended against imaging during periods of observation where imaging would not change practice (e.g. 48 h observation period after failed aspiration). By incorporating these components into our protocol we were able to decrease the overall radiation exposure from CTs and x-rays significantly. With an average of 32 admissions for PSP per year at our hospital, costs from the decreased rates of imaging were reduced by $39,456 per year.

While this quality improvement project succeeded in several aspects, this study had several limitations. First, given the rare nature of PSP, the significance of our results is limited by the small cohort included in the study. Additionally, our small cohort limits our ability to examine the various subsets within the study (e.g. outcomes for patients who have experienced more than one previous PSP) with any statistical reliability. As with all quality improvement work, we are also unable to definitively prove that our protocol was the direct cause of our results. However, there is a strong temporal correlation in our findings. While we feel the components of this protocol could be adopted at any institution that cares for patients with PSP, individualized efforts may be needed to tailor improvement in care at different institutions based on current practice patterns. Our study lays the groundwork for further investigations into best practices in the care of pediatric patients with PSP, which would likely be best accomplished on a large, multi-institutional scale. In addition to improving care for patients hospitalized with PSP, we hope that future research will also aim to decrease recurrence as this continues to be a significant problem for many patients with PSP.

## 4. Conclusions

Through adoption of an evidence-based protocol for the management of pediatric patients presenting with PSP, our institution was able to decrease LOS, diagnostic radiation exposure and costs. These outcomes were achieved without increasing the risk of clinical recurrence at 30 days or overall. Further evaluation of this protocol in a multicenter study may result in further opportunities to significantly improve the care of pediatric patients with PSP.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2020.09.048.

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