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Early Surgery for Spontaneous Pneumothorax Associated With Reduced Recurrence, Resource Utilization

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ABSTRACT

Background: Primary spontaneous pneumothorax (PSP) occurs in adolescent patients and frequently recurs. Reliable predictors of recurrence may identify candidates for early VATS (video-assisted thoracoscopic surgery). We hypothesize that demographic and clinical factors are associated with recurrence, and that earlier surgery is associated with decreased recurrence and resource utilization.

Methods: Patients between ages 5 and 21 treated for PSP at a single center from January 1, 2008 to June 30th, 2019 were identified. Presenting demographics, clinical management, and outcomes were analyzed, with focus on the first admission for PSP. "Early VATS" was defined as VATS during the first admission, and "late VATS" as VATS at any point after the first admission for a given side.

Results: Thirty-nine patients met inclusion criteria, with a total of 82 pneumothoraces. Following initial encounter, 48.7% had ipsilateral recurrence. Early VATS was associated with less recurrence ($P = 0.002$). No other predictive factors were associated with ipsilateral recurrence. Early VATS was associated with reduced overall recurrence ($P < 0.001$), admissions ($P < 0.001$), cumulative chest x-rays ($P = 0.043$), and cumulative hospital length of stay ($P = 0.022$) compared to late VATS.

Conclusions: While predictors of recurrence are not apparent at initial admission, early VATS is associated with decreased recurrence and resource utilization.

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Introduction

Primary spontaneous pneumothorax (PSP) is the accumulation of air in the pleural space in patients without underlying lung disease, presumed to occur due to spontaneous rupture of subpleural blebs and bullae. The incidence of PSP in children younger than 18 in the United States is reported at 3.4 per 100,000.[1] Risk factors reported for PSP include male sex, tall stature, smoking, family history of pneumothorax, connective tissue disorders such as Marfan syndrome, and asthma.[1-4]

Presently there are no management guidelines for PSP in the pediatric population. Practice guidelines for PSP in adults have been published by the American College of Chest Physicians (ACCP) and British Thoracic Society (BTS) and have historically been extrapolated to the pediatric population.[5-6] ACCP and BTS guidelines concordantly recommend observation in the emergency department for clinically stable patients with small pneumothoraces and tube thoracostomy and admission for unstable or large pnuemothoraces. Both sets of guidelines recommend surgical consultation for recurrent pneumothorax or for air leak persisting beyond 3-5 D. Limited by level of evidence and development for adult patients, these guidelines have not been uniformly implemented in the pediatric population and there is considerable variation in the management of pediatric PSP.[7]

Though video-assisted thoracoscopic surgery (VATS) has been shown to minimize recurrence of PSP by a number of bleb and pleural management approaches, there is a lack of consensus on the role and optimum timing for surgery.[1,8] To reduce unnecessary resource utilization and decrease recurrence, clinically useful risk factors for recurrent disease should be identified to assess candidacy for early VATS. In this single-center retrospective study, we characterized the clinical courses of adolescent and pediatric PSP cases treated both operatively and non-operatively. We hypothesized that there are demographic and clinical factors associated with ipsilateral disease recurrence, and that early management with VATS is associated with reduced recurrence and resource utilization.

Methods

Study setting and patient selection

A retrospective review of patients admitted to Riley Hospital for Children and other regional IU Health-affiliated hospitals from January 1, 2008 to June 30th, 2019 was performed. After Institutional Board Review and waiver of consent (IRB #1805561304), a patient list was generated including all admissions with ICD-9 and 10 diagnosis codes for primary spontaneous pneumothorax (J93.11, 512.81), spontaneous tension pneumothorax (J93.0, 512.0), unspecified pneumothorax (J93.9), other pneumothorax (J93.83, 512.89), or other air leak (J93.82, 512.84). Any prior admissions at outside hospitals were included if documentation of this admission was available.

Exclusion criteria

Each patient from the generated list was reviewed and those meeting any of the following criteria were excluded:

1. <5 Y of age at first pneumothorax
2. >21 Y of age at first pneumothorax
3. Recent heart, lung, chest wall, esophagus or spinal fusion surgery
4. Pneumothorax suspected to be of traumatic etiology
5. Other comorbidities to which pneumothorax was suspected to be secondary

Data collection

Study data were collected and managed using REDCap™; electronic data capture tools hosted at the Indiana Clinical and Translational Sciences Institute. Demographic information, past medical history, admitting service, radiographic, primary management strategy, chest tube procedural details and outcomes, CT (computed tomography) scan findings, VATS operative details, outpatient follow-up documentation, and subsequent readmissions were extracted from the electronic medical record. No cost or charge data was collected.

Definitions

A positive pneumothorax history was defined as any previous pneumothorax event – regardless of laterality – described in the ED (emergency department) visit note or admission note. Laterality of prior pneumothoraces was recorded if indicated in the medical record. Pneumothorax size was measured on the initial diagnostic chest radiograph in a standardized fashion at both the apex and hilum. Hilar radiograph measurements were obtained at the level of the carina by measuring horizontally from the visceral pleura to the interior costal surface. Apical radiograph measurements were obtained by measuring from the visceral pleura to the inferior aspect of the first rib.

The primary intervention was defined as observation, chest tube or VATS for all admissions. “Observation” was selected if the patient was admitted without placement of a chest tube and with a plan for chest radiograph monitoring, “chest tube” if a chest tube was placed initially without an observation period, or “VATS” if VATS (encompassing various bleb and pleural management approaches) was performed in the same or following day without first attempting observation or a chest tube. Failure of the primary intervention was defined as eventual need for additional intervention within that admission; chest tube exchange or positional adjustment was not considered chest tube failure if the patient was discharged with no further intervention. Final intervention was similarly defined as observation, chest tube, or VATS, but was labeled as such when it was the final management strategy that was attempted prior to discharge of the patient; this could be the same intervention as primary intervention if no management changes occurred.

Degree of pneumothorax resolution following chest tube placement was recorded as complete or incomplete according to the staff radiologist’s impression of the first post-placement radiograph obtained after chest tube insertion. Air leaks were considered active until the day that the surgical progress notes reported successful water seal, or until the date of chest tube removal if no successful water seal was ever achieved. Air leak duration was calculated as the number of days between chest

tube placement and successful water seal, or until the date of VATS for air leaks that persisted until surgery.

Readmission was defined as radiographically-proven pneumothorax requiring hospital admission in a patient with previous spontaneous pneumothorax in either lung; recurrence was defined as readmission for spontaneous pneumothorax in a previously affected lung. Unilateral disease was defined as presentation for pneumothorax in one lung only over the course of the study; bilateral disease was defined as presentation for pneumothorax in both lungs over the course of the study and not necessarily confined to mean concurrent presentation of both sides.

Study design and patient groupings

To thoroughly answer the hypothesis, two questions were raised regarding the details surrounding the first admission for PSP-related management. For calculations of predictors for recurrent disease, patients were separated into one of two groups for comparison and analyzed on a patient-level based on their first admission at our institution:

1. Recurrent disease: defined as patients who had readmissions for ipsilateral disease. Subjects fell into this group if they had more than one admission for disease on the same lung, irrespective of which side they presented with on their first admission.
2. Non-recurrent disease: defined as patients who never had more than one admission for a given side. This group did include those who were readmitted for disease on the contralateral side, but no more than one admission for a given side.

For calculations of hospital utilization based on timing of VATS, analysis was completed based on the encountered side managed, whereby one patient may be analyzed either once if they ever only had unilateral disease or twice, if they had bilateral disease. This approach was taken to simplify the analysis of patients with bilateral disease. Management of each diseased side was then separated into one of two management options, "early" versus "late VATS:"

1. Early VATS: was defined as VATS performed in the first admission for the affected side.
2. Late VATS: was any operation performed in any subsequent admission for that ipsilateral side.

Variables such as number of recurrences, admissions, hospital length of stay (LOS), number of chest tubes, and number of chest x-rays were counted and tallied over the patient's lifetime, and utility pre- and post-VATS were compared. For consistency, if a patient had a redo VATS, the first procedure was used to determine the cutoff for pre- and post-VATS calculations.

Statistical analysis

Descriptive variables were displayed as n with percentages or median with interquartile range (IQR) where applicable. Patients were omitted from an analysis if they were missing values for relevant variables. Bivariate analysis was used to compare recurrent versus nonrecurrent disease according to the first admission to identify potential predictors of recurrence; early versus late VATS outcomes were similarly compared. Categorical variables were compared by Fisher's exact test or Chi-Square, where applicable. Continuous variables were compared by Mann-Whitney-U or Kruskal-Wallis test, where applicable. A $P < 0.05$ was significant.

Table 1 – Patient demographics.

	n = 39
Gender	
Male	32 (82%)
Female	7 (18%)
Risk factors	
Smoker	7 (18%)
Asthma	6 (15%)
Family history	6 (15%)
Connective tissue disease	4 (10%)
Disease laterality	
Unilateral	27 (69%)
Bilateral	12 (31%)
Number of PSP admissions	
1	17 (44%)
2	10 (26%)
3+	12 (30%)
	Median [IQR]
Age	15 [14-16]
BMI	18.5 [16.8-20.2]
Number of PSP admissions	2 [1.0-3.75]
Follow-up time (months)	23 [10.5-53.6]

All demographic data collected at the time of first admission.
BMI = body mass index; IQR, interquartile range; PSP = primary spontaneous pneumothorax.

Results

Patient demographics

Thirty-nine patients met inclusion criteria. These 39 patients had a total of 82 pneumothoraces. The majority were male (82%) with a median age of 15 Y (IQR 14-16 Y) and median BMI of 18.5 (IQR 16.8-20.2) at first admission for PSP. Seven patients had a personal history of smoking (18%), six had a history of asthma (15%), and six had a family history of PSP (15%). Connective tissue disease was diagnosed in four patients (10%) either before or after initial PSP encounter. The median number of admissions per patient was two (IQR 1-3.75), with 17 patients admitted only once (44%), 10 admitted twice (26%), and 12 admitted three or more times (31%). From first admission to last known follow-up, 27 patients presented with unilateral disease only (69%) and 12 had bilateral disease (31%). Median follow-up time was 23 MO (IQR 10.5-53.6 months). (Table 1)

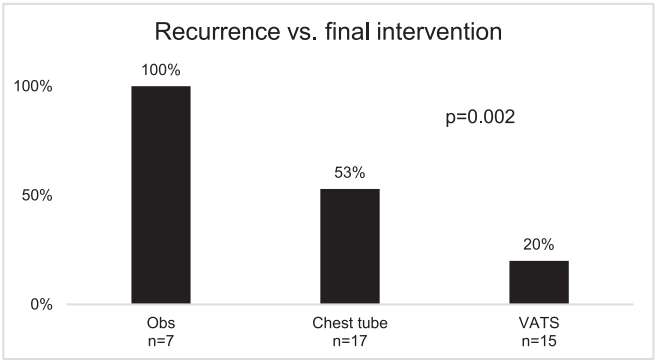

Fig. 1 – Ipsilateral recurrence rate by final intervention during first admission. Abbreviations: Obs, observation; VATS video assisted thoracoscopic surgery. Color version of figure is available online.

Management at first encounter

At first encounter, 15 patients were admitted to a surgical service (38%), 10 to a pulmonology service (26%), 12 to a general pediatric or hospitalist service (31%), and two were managed by outpatient follow-up only (5%). There was no association between admitting service and the use of invasive (chest tube or VATS) initial management ($P = 0.1229$) or the use of VATS at any point before discharge ($P = 0.1127$). Initial and final management strategies differed in 18 first encounters (46%). Overall median length of stay was 6.0 D (IQR 3-10.75) and did not differ significantly by admitting service ($P = 0.88$).

Operative management

Thirty-two patients had at least one operation during the study period for a total of 48 operations, including six ipsilateral reoperations. All operations were performed thoracoscopically. Twenty-six were unilateral left-sided VATS (55%), 20 were unilateral right-sided VATS (43%), and one was bilateral VATS under the same anesthetic event (2%). The bilateral operation was considered as two separate unilateral operations for analyses. VATS most commonly included blebectomy (87%) with pleural management by pleurectomy (52%), mechanical or chemical pleurodesis (29%), or no pleural management (6%). Postoperative complications included ipsilateral recurrence (n = 8), ipsilateral reoperation in a subsequent admission for recurrence (n = 5) or in the same admission for persistent air leak (n = 1), and empyema with chest tube site cellulitis (n = 1). (Table 2)

Recurrence

Nineteen (48.7%) patients had ipsilateral recurrence following their initial encounter. Recurrence varied significantly by final intervention preceding discharge: 100% recurrence was observed following observation, 53% following chest tube, and 20% following VATS ($P = 0.002$) (Fig. 1). Median times to recurrence in these treatment groups were 167 (IQR 9.5-351), 11 (IQR 10-115), and 1149 D (IQR 666.5-1631.5), respectively.

Table 2 – Operative management.

	n = 48
Timing	
1st admission	24 (50%)
2nd admission	16 (33%)
3rd admission or later	8 (17%)
Laterality	
Left	26 (54%)
Right	20 (42%)
Bilateral	1 (4%)
Approach	
Blebectomy only	3 (6%)
Blebectomy + pleurectomy	25 (52%)
Blebectomy + pleurodesis	14 (29%)
Pleural management only	6 (13%)
Complications	
Ipsilateral recurrence	8 (17%)
Ipsilateral reoperation, subsequent admission	5 (10%)
Ipsilateral reoperation, same admission	1 (2%)
Empyema with chest tube site cellulitis	1 (2%)

Timing defined according to the number of previous admissions for the lung operated on. Note 23 patients underwent VATS in first admission (see "Early versus Late VATS") with one reoperation in the first admission, thus 24 total VATS observed during first admissions. Bilateral VATS counted as two single operations.

Recurrence also varied significantly by initial intervention received ($P = 0.032$). In patients initially receiving a chest tube, complete resolution of the pneumothorax on the immediate post-placement chest x-ray was associated with recurrence ($P = 0.034$).

No other factors were associated with recurrence, including those related to patient demographics, PSP risk factors, findings on admission, and initial management strategy (Table 3).

Early versus late VATS

Excluding six ipsilateral reoperations, VATS was performed 42 times in 32 patients. Twenty-three operations (one bilateral) took place in the first admission for that lung ("early VATS"), and the remaining were in subsequent admissions after the first admission for that given side ("late VATS"). Early VATS was performed on a median of hospital D of 1 (IQR 1-4.5). While there was no significant difference in the total days with air leak ($P = 0.701$) or cumulative number of chest tubes placed across all presentations ($P = 0.078$), early VATS was associated with reduced overall recurrence ($P < 0.001$), overall admissions for PSP ($p<0.001$), cumulative number of chest x-rays obtained related to PSP management ($p=0.044$), and cumulative hospital length of stay ($p=0.022$) when compared to those who underwent late VATS (Table 4). There was no difference in the number of recurrences or admissions post-VATS ($p > 0.999$ and $p=p=0.742$, respectively).

Table 3 – Predictors for recurrence of PSP.

Findings	Recurrent (n = 19)	Nonrecurrent (n = 20)	P-value
Patient basics			
Male	16 (84.2%)	16 (80.0%)	>0.999
Median Height (cm)	176.5 [10.0]	175.2 [17.3]	0.702
Median BMI	19.4 [4.3]	17.5 [4.7]	0.142
Risk factors			
Smoker	3 (15.8%)	4 (20.0%)	>0.999
Asthma	4 (21.1%)	3 (15.0%)	0.695
Family history of PSP	4 (21.1%)	2 (10.0%)	0.408
Other connective tissue disease	1 (5.3%)	2 (10.0%)	>0.999
First admission findings			
Left sided disease (versus right)	13 (68.4%)	13 (65.0%)	>0.999
Presenting median pneumothorax size			
Apical (cm)	3.0 [2.6]	4.2 [2.9]	0.173
Hilar (cm)	0.75 [1.0]	1.6 [2.8]	0.406
Need for chest tube	11 (57.9%)	17 (85.0%)	0.082
Ptx resolution after chest tube placed	4 (40.0%)	1 (6.3%)	**0.034**
Presence of air leak	3 (30.0%)	7 (43.8%)	0.483
Median air leak duration (days)	3.0 [11.0]	5.0 [6.0]	0.950
Bleb disease on CT scan	7 (58.3%)	10 (76.9%)	0.411
Admission to surgery (vs other service)	6 (31.6%)	9 (45.0%)	0.389
Initial treatment on first admission			
Observe (n=15)	11 (57.9%)	4 (20.0%)	**0.032**
Chest tube (n=22)	8 (42.1%)	14 (70.0%)	
VATS (n=2)	0 (0%)	2 (10.0%)	
Final treatment on first admission			
Observe (n=7)	7 (36.9%)	0 (0%)	**0.002**
Chest tube (n=17)	9 (47.4%)	8 (40.0%)	
VATS (n=15)	3 (15.8%)	12 (60.0%)	

Data here is expressed as n (%) or median [IQR].
Bold indicates a significant finding.
BMI = body max index; IQR = interquartile range; PSP = primary spontaneous pneumothorax; ptx = pneumothorax; VATS = video-assisted thoracoscopic surgery.

Table 4 – Hospital utilization in Early versus Late VATS.

Findings	Early VATS (n = 23)	Late VATS (n = 19)	P-value
Total recurrences overall	0 [1]	1 [1]	**<0.001**
Total recurrences post-VATS	0 [0]	0 [1]	>0.999
Total admissions overall	1 [1]	2 [1]	**<0.001**
Total admissions post-VATS	0 [1]	0 [1]	0.742
Cumulative hospital LOS (days)	8 [7]	14 [12]	**0.022**
Cumulative number of chest tubes	2 [2]	3 [3]	0.078
Cumulative air leak days	4.5 [5.5]	7.0 [8.0]	0.701
Cumulative number of CXR	14 [9]	18 [14]	**0.044**

Cases were reviewed on a lung encounter level; thus, each patient was reviewed once if they unilateral disease, or twice if they had bilateral disease. Variables were collected cumulatively over the patient's disease course as a total count, rather than on an admission-basis, and expressed here as median for the group [interquartile range].
Bold indicates a significant difference.
CXR = chest x-ray; LOS = length of stay; VATS = video-assisted thoracoscopic surgery.

Discussion

This single-center retrospective study of pediatric and adolescent patients with first-time primary spontaneous pneumothorax demonstrated an overall recurrent ipsilateral disease rate of 48.7% over a 2-Y follow-up period. Recurrent disease was difficult to predict early in the treatment course. More invasive interventions were associated with lower recurrence rates. In all patients who underwent VATS at their initial presentation, ipsilateral recurrence occurred at a rate of 20%, and earlier surgery was associated with a lower number of recurrences, overall readmissions, and resource utilization.

Overall recurrence was 48.7%, comparable to that of similar studies ranging from 37%-46%.[1,8,9] When stratified by intervention, recurrence rates were generally comparable to reported literature values with the exception of recurrence following observation. Observation with or without supplemental oxygen was associated with 100% recurrence in this study, more than double the rate reported by Lopez (33%) and Soler (40%).[1,8] This may be partially attributed to operational definitions of recurrence. In other studies, an admission was considered recurrent only if there was documented radiographic resolution of the previous pneumothorax. In contrast, our definition did not consider the degree of resolution of the previous pneumothorax, as incomplete resolution was often present at discharge. Many patients, especially those receiving observation only, progressed to full resolution of symptoms despite residual apical air that was felt to be stable, clinically insignificant and unlikely to merit further prolonged hospitalization. For the sake of consistency and to reflect patient disease burden, any future admissions for ipsilateral disease with positive pneumothorax in such patients were considered recurrences, though they may have represented interval expansion of known, unresolved pneumothoraces.

Recurrence rates following more invasive interventions were consistent with literature values. Chest tube drainage, whether by pigtail catheter or conventional tube thoracostomy, was associated with 53% recurrence, within the range reported in similar studies (36%-58%).[8,9] VATS was associated with 20% recurrence, approximating the range reported in similar studies (14%-14.6%).[1,8] Here, we found differences in recurrence rates between the final three treatment groups during their first admission were significant ($P = 0.002$), with VATS associated with fewer recurrences. Lopez and Soler *et al.* stratify more broadly by non-operative versus operative management, but similarly find a significant reduction in recurrence with operative management.[1,8] While Brown *et al.* demonstrate non-inferiority in conservative management to chest tube drainage in a new open-label randomized trial, their study has only a 12-MO follow up time, does not account for or look at outcomes of VATS, and the close observation periods at H 24 and 72, WK 2, 4, and 8, and MO 6 and 12 allowed for close reassurance and monitoring that would otherwise result in potential readmission and hospital utilization.[10]

This study found only initial and final treatments to be predictive of recurrence ($P = 0.002$). There were no clinical, demographic, or radiographic factors predictive of future ipsilateral recurrence identifiable within the first admission. Though pneumothorax resolution following chest tube placement was associated with recurrence, this is likely not clinically useful for recurrence prediction. It may represent clinicians' overconfidence in the post-placement chest x-ray as an indicator of true resolution, when in fact a lower threshold for VATS would have been more appropriate. The simple aspiration test was found to be predictive of chest tube failure in a recent prospective study by Leys *et al.* and may be a more useful clinical factor to consider in the decision to proceed from thoracostomy to VATS.[11]

None of the demographic risk factors for PSP were found to be predictive of recurrent disease in this study. Other pediatric series have also been unable to identify such risk factors, though Soler *et al.* found height to be predictive.[1,12] With regard to CT scan findings, there was no significant association between detection of blebs and recurrence. This further confirms the limited utility of routine CT imaging in surgical decision-making for first-time PSP.[1,13] Thus, while VATS is highly effective at reducing recurrence, the 40%-50% of patients who will recur remain difficult to identify before recurrence on the basis of demographics and radiographic findings.

Considering the timing of VATS, patients who underwent early VATS had significantly fewer overall recurrences and admissions compared to patients undergoing late VATS. These differences are eliminated when considering the post-VATS period only, thereby suggesting the overall differences are due to management changes that occurred pre-VATS. In addition to fewer admissions and recurrences, early VATS resulted in significantly fewer cumulative hospital stays and number of chest x-rays.

Though other single-institution PSP reviews report similar healthcare utilization outcomes with early VATS, the same studies also suggest late VATS may be more cost-effective.[1,14] Additionally, a recent multi-institutional prospective study by the Midwest Pediatric Surgery Consortium provides compelling evidence for non-invasive initial management, reserving VATS only for patients failing a simple aspiration test.[11] Though our findings weakly suggest early VATS may achieve disease resolution more efficiently, we were unable to retrospectively identify clinically significant indicators of early VATS candidacy, and thus this study does not support an early VATS approach for all PSP patients at first presentation. However, it does highlight the risks of non-invasive treatment, including prolonged and repeated hospitalization, and may be of importance for patient and family counseling in discussing early operative interventions compared to alternative management options.

Limitations to this study include sample size, retrospective nature, and loss to follow-up due to single-center design. Only 39 patients met inclusion criteria for the study in an 11.5 Y period, a comparatively small sample size. However, we observed that a smaller proportion of early VATS patients experienced post-VATS recurrences (5of 23; 21.7%), compared to late VATS patients (5of 19; 26.3%). This reduction in recurrence rates for early VATS patients results in a relative risk reduction (RRR) of 17.4% and an absolute risk reduction (ARR) of 4.6%, which is equivalent to a number needed to treat (NNT) of 22 patients. Despite the small sample size and retrospective nature of the present study, it may be useful as a guide for future prospective pilot studies. Additionally, the decision for the timing of VATS was non-random and likely a function of surgeon and

patient preference, thus limiting conclusions regarding effectiveness at reducing recurrence. Finally, recurrences presenting to other centers were not captured, and recurrence rates may be underestimated as presented here.

Conclusions

PSP is a rare condition most often occurring in lean, male adolescents which notoriously recurs. We demonstrate in a single-center retrospective study that while predictive factors for recurrent PSP are not immediately apparent in an initial admission, management with early VATS within the first hospitalization for PSP is associated with reduced recurrence and resource utilization compared to late VATS. Future prospective studies are needed to assess timing of VATS in terms of cost effectiveness and quality of life.

Author contributions

Cody Tragesser and Niloufar Hafezi conducted data collection, analysis, and manuscript drafting. Cameron Colgate assisted with statistical analysis. Brian Gray critically reviewed the manuscript for important intellectual content and provided major manuscript revisions. Matthew Landman supervised the data collection and analysis, critically reviewed the manuscript for important intellectual content and provided major manuscript revisions. All authors assisted in study conception, study design, and approved the final manuscript as submitted.

Disclosures

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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