

Timing of VATS for Primary Spontaneous Pneumothorax in Pediatric Patients: A NSQIP- P Analysis

Alexa G. Turpin

agturpin12@gmail.com

Nemours Children's Health

Paulo Castro

UConn Health

Lindsey Asti

Nemours Children's Health

Loren Berman

Nemours Children's Health

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Abstract

Introduction:

Primary spontaneous pneumothorax (PSP) classically presents in adolescent males and is thought to be due to the rupture of subpleural blebs or bullae. There is evidence to support early operative intervention with video-assisted thoracoscopic surgery (VATS) for segmental resection and pleurodesis. Despite this evidence, there is persistent variability in management regarding indications for and timing of surgery, which can lead to excess length of stay. We sought to quantify the incidence of delayed VATS and test for associations between patient characteristics and delayed intervention.

Methods

This is a retrospective cohort study utilizing the American College of Surgeons' National Surgical Quality Improvement Program-Pediatric (NSQIP-P) database. The NSQIP-P database was queried to identify all patients aged 11 and 18 who underwent urgent or emergent VATS with pleurodesis from 2013–2023. Patients were divided into two groups: early VATS (preoperative stay ≤ 1 day) and delayed VATS (preoperative stay > 1 day). A multivariable logistic regression model was fit to identify patient characteristics associated with delayed VATS. A Cochran-Armitage test was performed to assess trends toward early VATS over the last decade.

Results

A total of 386 patients underwent early VATS, and 227 patients underwent delayed VATS. Females were more likely to have delayed VATS compared to males (51.9% vs 34.8%, $p = 0.003$). In the multivariable model, females had 2.0 higher odds of undergoing delayed VATS compared to males (95% confidence interval 1.3–3.3). Cochran-Armitage test revealed no significant trend toward early VATS ($p = 0.92$).

Conclusion

Between 2013 and 2023, there has not been a significant trend towards early VATS. Female sex was associated with delayed VATS. A standardized approach to management of PSP with early VATS could help to mitigate gender disparities.

Level of Evidence

Level III

Introduction

Primary spontaneous pneumothorax (PSP) occurs when there is spontaneous rupture of subpleural blebs or bullae, leading to the presence of air in the pleural space. It occurs in the absence of trauma and is not seen in patients with underlying pulmonary pathology, excluding bleb disease [1]. The incidence of PSP in children under the age of 18 years is estimated to be 3.41 per 100,000, with an average age at presentation of 15.1 years and a strong male predilection (4 times more common in males compared to females) [2, 3].

Although PSP is a relatively common condition managed by pediatric surgeons, there is substantial variability in the approach to the management of these patients. Some surgeons prefer initial non-operative treatment with insertion of chest tube or pigtail catheter for drainage, and others advocate for early surgical intervention with video-assisted thoracoscopic surgery (VATS), bleb resection, and pleurodesis [4]. Patients who have initial chest tube/pigtail placement which fails to definitively manage the pneumothorax and then undergo VATS may be at risk for excess length of stay [3]. There is an increasing body of literature supporting earlier decision for surgical management with VATS and efforts to identify clinical characteristics of patients who would benefit most from early VATS, as early as 6 to 8 hours from admission [3, 5–8]. The purpose of this study was to quantify the incidence of delayed VATS and test for associations between patient characteristics and delayed VATS.

Methods

Data and study population

This was a retrospective cohort study. The American College of Surgeons' (ACS) National Surgical Quality Improvement Program Pediatric (NSQIP-P) participant use file (PUF) database was queried from 2013–2023 to identify all children between the ages of 11 and 18 years who underwent urgent or emergent VATS with pleurodesis using Current Procedural Terminology (CPT) code 32650 as either the primary or concurrent procedure. Patients were excluded if the case type was classified as elective. Patients were also excluded if they had any of the following comorbidities or conditions: ventilator dependence, major or severe cardiac risk factors, preoperative nutritional support, septic shock, inotropic support, current malignancy, or were American Society of Anesthesiology (ASA) class 4 or 5 (Fig. 1).

The NSQIP-P PUF includes data from over 130 hospitals. Trained reviewers at each participating hospital extract the data using definitions established by the ACS, capturing the first 35 consecutive cases meeting the ACS definition over 8-day cycles [9, 10]. Extracted data is deidentified with respect to both the patient and the participating institution.

After patients were identified using our inclusion criteria, they were further categorized into two groups: early VATS (preoperative length of stay (LOS) $\leq$ 1 day) and delayed VATS (preoperative length of stay $>$ 1 day). Patients with missing preoperative LOS were excluded. Twenty-four hours was used as a cutoff based on the existence of published treatment algorithms which show that patients whose

pneumothorax does not improve after an aspiration trial or period with chest tube should undergo VATS [8]. This 24-hour timeframe should allow for sufficient time for improvement of the pneumothorax with chest tube placement. To explore whether observed associations between patient characteristics and delayed VATS were consistent with variable definitions of “delayed,” sensitivity analyses were performed using different cut-offs (≤ 0 days versus > 0 days and ≤ 2 days versus > 2 days).

This study was deemed exempt by our Institutional Review Board.

Primary characteristics and outcomes

Patient demographics of interest included age, sex, race, and ethnicity. Clinical factors included body mass index (BMI), asthma, chronic lung disease, preoperative oxygen support, gastrointestinal disease (defined as necrotizing enterocolitis, pneumoperitoneum on imaging, gastroesophageal reflux disease, unrepaired pyloric stenosis, inflammatory bowel disease, or diagnosis of tracheoesophageal fistula), previous cardiac surgery, minor cardiac risk factors, steroid use within 48 hours prior to surgery, hematologic disorders, systemic inflammatory response syndrome (SIRS), urgent or emergent case status, and ASA classification.

The primary outcome was early versus delayed VATS. Secondary outcomes included postoperative LOS, readmission, reoperation, and composite morbidity. Composite morbidity was defined as the occurrence of any one of the following complications: surgical site infection (SSI) (superficial, deep, and organ space), wound disruption, SIRS or sepsis, unplanned intubation, pneumonia, blood transfusion volume of 25 mL/kg intra-operatively or in the first 72 hours after surgery, acute renal failure, progressive renal insufficiency, cardiac arrest, ventricular tachycardia, coma, stroke, seizure, nerve injury, intraventricular hemorrhage (IVH), urinary tract infection, and central line infection. This variable was further categorized into surgical and non-surgical morbidity. Surgical morbidity included SSIs, wound disruption, nerve injury, transfusion > 25 cc/kg, and sepsis. All other postoperative complications were included in non-surgical morbidity.

Statistical analysis

All continuous variables were reported as a median with an interquartile range (IQR) and compared using a Mann-Whitney U test. Pearson’s chi-square or Fisher’s exact tests were used for categorical variables where appropriate. All statistical tests were 2-sided. A p-value < 0.05 was considered statistically significant. Descriptive and comparative statistics of preoperative variables were performed. To investigate if there was a relationship between patient characteristics and timing of VATS, a univariable logistic regression was performed. A multivariable logistic regression was then fit using patient factors from the univariable analysis with a p-value < 0.25 as potential predictors. Backwards elimination was performed with the final model fit checked using the Hosmer-Lemeshow goodness of fit test. Each predictor is presented with an odds ratio (OR) and 95% confidence interval (CI). Postoperative outcomes were compared between patients who underwent early versus delayed VATS. Changes over time in the

frequency of early vs delayed VATS were assessed with a Cochran-Armitage trend test. The median postoperative hospital LOS was compared between 2013 and 2023. These analyses was completed utilizing STATA/SE 15.1 statistical software (StataCorp LLC, College Station, TX) [11].

Results

a. Preoperative Patient Characteristics

Between 2013 and 2023, a total of 386 patients (63.0%) underwent early VATS, and 227 patients (37.0%) underwent delayed VATS. The median age of those undergoing early versus delayed VATS was similar (16.4 years [IQR 15.5–17.2]) vs. 16.5 years [IQR 15.4–17.1], $p = 0.42$). Females were more likely to have delayed VATS compared to males (51.9% vs 34.8%, $p = 0.003$). There were statistically significant differences in both race and ethnicity between the early vs. delayed VATS group (Table 1).

Table 1

Patient demographic and clinical factors for those who underwent early (≤ 1 day) versus delayed (> 1 day) video-assisted thoracoscopic surgery (VATS)

Median age, years (IQR)	Early VATS	Delayed VATS	p-value
	n = 386	n = 227	
	16.4 (15.5–17.2)	16.5 (15.4–17.1)	0.42
Sex, n (%)	347 (65.2)	185 (34.8)	0.003
Male	39 (48.1)	42 (51.9)	
Female			
Race, n (%)	272 (66.0)	140 (34.0)	0.05
White	41 (65.1)	22 (34.9)	
Asian	13 (50.0)	13 (50.0)	
Black	60 (53.6)	52 (46.4)	
Other/Unknown			
Ethnicity, n (%)	296 (65.6)	155 (34.4)	0.03
Non-Hispanic	58 (59.8)	39 (40.2)	
Hispanic	32 (49.2)	33 (50.8)	
Unknown			
Median BMI percentile (IQR)* (n = 534)	20.6 (5.5–46.1)	20.4 (5.4–43.0)	0.94
BMI ≥ 30 , n (%) (n = 534)	6 (1.7)	1 (0.5%)	0.24
Asthma, n (%)	15 (3.9)	5 (2.2)	0.26
Chronic Lung Disease, n (%)	6 (1.6)	4 (1.8)	0.85
Oxygen Support, n (%)	56 (14.5)	28 (12.3)	0.45
GI Disease, n (%)	8 (2.1)	4 (1.8)	0.79
Previous Cardiac Surgery, n (%)	2 (0.5)	1 (0.4)	0.89
Minor CRFs, n (%)	15 (3.9)	6 (2.6)	0.41

*Using 2000 CDC growth charts for the US

IQR = interquartile range, BMI = body mass index, GI = gastrointestinal, CRF = cardiac risk factors, SIRS = systemic inflammatory response syndrome, ASA = American Society of Anesthesiologists

Median age, years (IQR)	Early VATS n = 386	Delayed VATS n = 227	p-value
	16.4 (15.5–17.2)	16.5 (15.4–17.1)	0.42
Steroid use, n (%)	3 (0.8)	3 (1.3)	0.51
Hematologic Disorder, n (%)	1 (0.3)	3 (1.3)	0.12
SIRS, n (%)	7 (1.8)	6 (2.6)	0.49
Past Childhood Malignancy, n (%)	2 (0.5)	0 (0.0)	0.28
Case Status, n (%)	257 (60.3)	169 (39.7)	0.04
Urgent	129 (69.0)	58 (31.0)	
Emergent			
ASA Class, n (%)	53 (63.1)	31 (36.9)	0.38
1	248 (64.8)	135 (35.2)	
2	85 (58.2)	61 (41.8)	
3			
*Using 2000 CDC growth charts for the US			
IQR = interquartile range, BMI = body mass index, GI = gastrointestinal, CRF = cardiac risk factors, SIRS = systemic inflammatory response syndrome, ASA = American Society of Anesthesiologists			

b. Multivariable analysis

After adjusting for ethnicity, the odds of undergoing a delayed VATS among females was 2.0 (95% CI 1.3–3.3) times the odds of undergoing a delayed VATS among males. The odds of undergoing delayed VATS for patients with unknown ethnicity was 2.0 (95% CI 1.2–3.4), compared to non-Hispanic patients. The odds of undergoing delayed VATS for patients of Hispanic ethnicity was 1.3 (95% CI 0.8–2.0) compared to non-Hispanic patients. See Table 2.

Table 2
Multivariable logistic regression model for
delayed (> 1 day) video-assisted
thoroscopic surgery (VATS)

Characteristic	OR (95% CI)
Sex	Ref.
Male	2.0 (1.3–3.3)
Female	
<i>Ethnicity</i>	Ref.
Non-Hispanic	1.3 (0.8-2.0)
Hispanic	2.0 (1.2–3.4)
Other/Unknown	
CI = confidence interval, OR = odds ratio	

C. Sensitivity Analysis

When the time cut-off for early versus delayed VATS was adjusted to be ≤ 0 days versus > 0 days, females did not have higher odds of undergoing delayed VATS. However, when the time cut-off was adjusted so that early VATS was defined as ≤ 2 days and delayed VATS was defined as > 2 days, females had 1.90 times higher odds of undergoing delayed VATS (95% CI 1.14–3.15) compared to males.

d. Trends Over Time

Between 2013–2023, there was no significant trend identified toward early or delayed VATS ($p = 0.92$). In 2013, 64% of patients underwent early VATS and in 2023, 62% of patients underwent early VATS (Fig. 2).

e. Postoperative Outcomes

There were no significant differences in composite comorbidity, surgical morbidity, or non-surgical morbidity in patients who underwent early versus delayed VATS. The median postoperative LOS was 3 days (IQR 3–5 days) in the early VATS group and 3 days (IQR 3–5 days) in the delayed VATS group. The proportion of surgical site infections, pneumonia, and bleeding requiring transfusion were similar between patients who underwent early compared to delayed VATS (Table 3).

Table 3
30-day postoperative outcomes between patients undergoing early (≤ 1 day) versus delayed (> 1 day) video-assisted thoracoscopic surgery (VATS)

Outcome, n (%)	Early VATS n = 386	Delayed VATS n = 227	p-value
Composite morbidity	4 (1.0)	0 (0.0)	0.12
Surgical morbidity	2 (0.5)	0 (0.0)	0.28
Deep SSI	1 (0.3)	0 (0.0)	0.44
Bleeding Requiring Transfusion	1 (0.3)	0 (0.0)	0.44
Non-surgical morbidity	3 (0.8)	0 (0.0)	0.18
Pneumonia	1 (0.3)	0 (0.0)	0.44
Related readmissions	6 (1.6)	3 (1.3)	0.82
Related reoperation	17 (4.4)	11 (4.9)	0.80
Median postoperative LOS, days (IQR)	3 (3–5)	3 (3–5)	0.84
IQR= interquartile range, LOS = length of stay, SSI = surgical site infection			

Discussion

Multiple studies have supported the effectiveness of early VATS in adolescents presenting with primary spontaneous pneumothorax. VATS has been demonstrated to be safe and effective and is also associated with a decreased risk of recurrent spontaneous pneumothorax, compared to patients who are managed conservatively. If a patient has a prolonged air leak after trial of aspiration or chest tube placement, then it is unlikely that the child will improve without operative management [6]. In patients with a prolonged air leak or enlarging pneumothorax, the decision for VATS should be made expeditiously in an effort to reduce overall hospital stay, allowing for earlier discharge for patients and families and decreased healthcare utilization [8, 12].

Despite recent literature demonstrating that early VATS reduces overall hospital length of stay, healthcare costs, and need for hospital readmission, our 10-year review of the pediatric NSQIP database does not reveal a trend towards earlier VATS [5]. Optimizing length of stay is crucial for children. Decision for early VATS allows for a quicker discharge, meaning that children will be able to return to school and activities more expeditiously and caregivers can return to work faster. Because there is no increased risk of early postoperative complications between those who undergo early VATS compared to delayed VATS, clinicians caring for these children should make the decision for operative management early. When patients have an ongoing air leak at time of presentation (as demonstrated by chest tube placement or enlargement of pneumothorax on sequential films), the decision to proceed with VATS should be made rather than allowing a trial for possible resolution of the air leak.

We sought to identify patient-related risk factors for delayed VATS and found that female gender and ethnicity were associated with delayed VATS. The ethnicity association is difficult to interpret, since it was driven by patients with unknown ethnicity. International sites participating in NSQIP-P are not permitted to ask patients' race and ethnicity, so this may account for a percentage of patients with unknown race and ethnicity [13]. Additionally, race and ethnicity are self-reported, and patients may prefer not to answer.

The most notable and clinically relevant finding is that female patients were more likely to undergo delayed VATS compared to their male counterparts. This finding remained significant in a sensitivity analysis, where early VATS was defined as ≤ 2 days. PSP occurs much more commonly in males compared to females, occurring four times more often in males [2, 3]. It is possible that clinicians are more likely to pursue further diagnostic work-up in female patients with PSP to eliminate the possibility of other underlying etiologies accounting for pneumothorax in these patients, since females are not the classic patient demographic with PSP. This could lead to a delay in the decision for VATS. The evidence for safety and effectiveness of early VATS applies to both male and female patients [8, 12]. Additionally, a retrospective review found that post-menarchal females had a higher rate of recurrent pneumothorax when managed conservatively, compared to their male counterparts [14]. Females undergoing VATS, however, had a lower rate of postoperative recurrent pneumothorax compared to males undergoing VATS [15]. It is important to consider primary spontaneous pneumothorax as cause of pneumothorax in female patients and to manage them similarly to their male counterparts with early VATS, if clinically indicated.

Interestingly, no comorbidities, including asthma, chronic lung disease, structural respiratory conditions, minor cardiac risk factors, and gastrointestinal disease were associated with higher odds of undergoing delayed VATS. This is likely because children with PSP are generally healthy and have only minor comorbidities which are unlikely to affect decision for time to VATS.

The major limitations of this study are those inherent to the NSQIP-P database. First, NSQIP-P only includes data from participating hospitals. Second, there are no hospital identifiers within NSQIP-P; there may be some hospitals who have protocolized early VATS, but we were unable to adjust for hospital-level variation. Next, the hospitals participating in NSQIP-P have changed over the last decade, which could have affected the results, most notably with regard to the trends over time. Also, NSQIP-P does not capture all cases of VATS, only a sampling of cases. Because patients are not required to report their race and ethnicity, some may choose not to. Lastly, there is no way to differentiate between patients presenting with their first episode of spontaneous pneumothorax and patients presenting with recurrent spontaneous pneumothorax who may have been previously managed non-operatively and would be more likely to have early VATS in the setting of a recurrence.

Future directions should focus on implementation of standardized care pathways where the decision for management with VATS is made when a patient fails a trial of observation with serial films, aspiration or chest tube drainage. This could mitigate the gender disparities observed in this study. This study should

be repeated in the future after successful dissemination and implementation of such pathways to evaluate the impact on this gender disparity.

Conclusion

There is an increasing body of literature demonstrating the benefits of early VATS in adolescent patients with primary spontaneous pneumothorax. Over the last 10 years, however, there has been no change in the percentage of patients undergoing early VATS. Female patients are more likely to undergo delayed VATS, possibly due to unconscious bias and the predisposition of PSP to occur in male patients. A standardized care pathway where patients undergo early VATS could help to mitigate gender disparities which can affect care.

Abbreviations

ASA, American Society of Anesthesiology

CPT, Current Procedural Terminology

IQR, interquartile range

IVH, intraventricular hemorrhage

LOS, length of stay

NSQIP-P, National Surgical Quality Improvement Program-Pediatric

PSP, primary spontaneous pneumothorax

SIRS, systemic inflammatory response syndrome

SSI, surgical site infection

VATS, video-assisted thoracoscopic surgery

Alexa Turpin – conceptualization, methodology, project administration, visualization, writing – original draft

Paulo Castro – conceptualization, data curation, formal analysis, visualization, writing – reviewing and editing

Lindsey Asti – methodology, validation, writing – reviewing and editing

Loren Berman – conceptualization, methodology, supervision, writing – reviewing and editing

Declarations

Conflicts of Interest:

The authors declare there are no competing interests associated with this study.

Disclosures:

American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors

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Retrospective comparative study

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Author Contribution

A.G.T. – conceptualization, methodology, project administration, visualization, writing – original draft P.C. – conceptualization, data curation, formal analysis, visualization, writing – reviewing and editing L.A. – methodology, validation, writing – reviewing and editing L.B. – conceptualization, methodology, supervision, writing – reviewing and editing

Data Availability

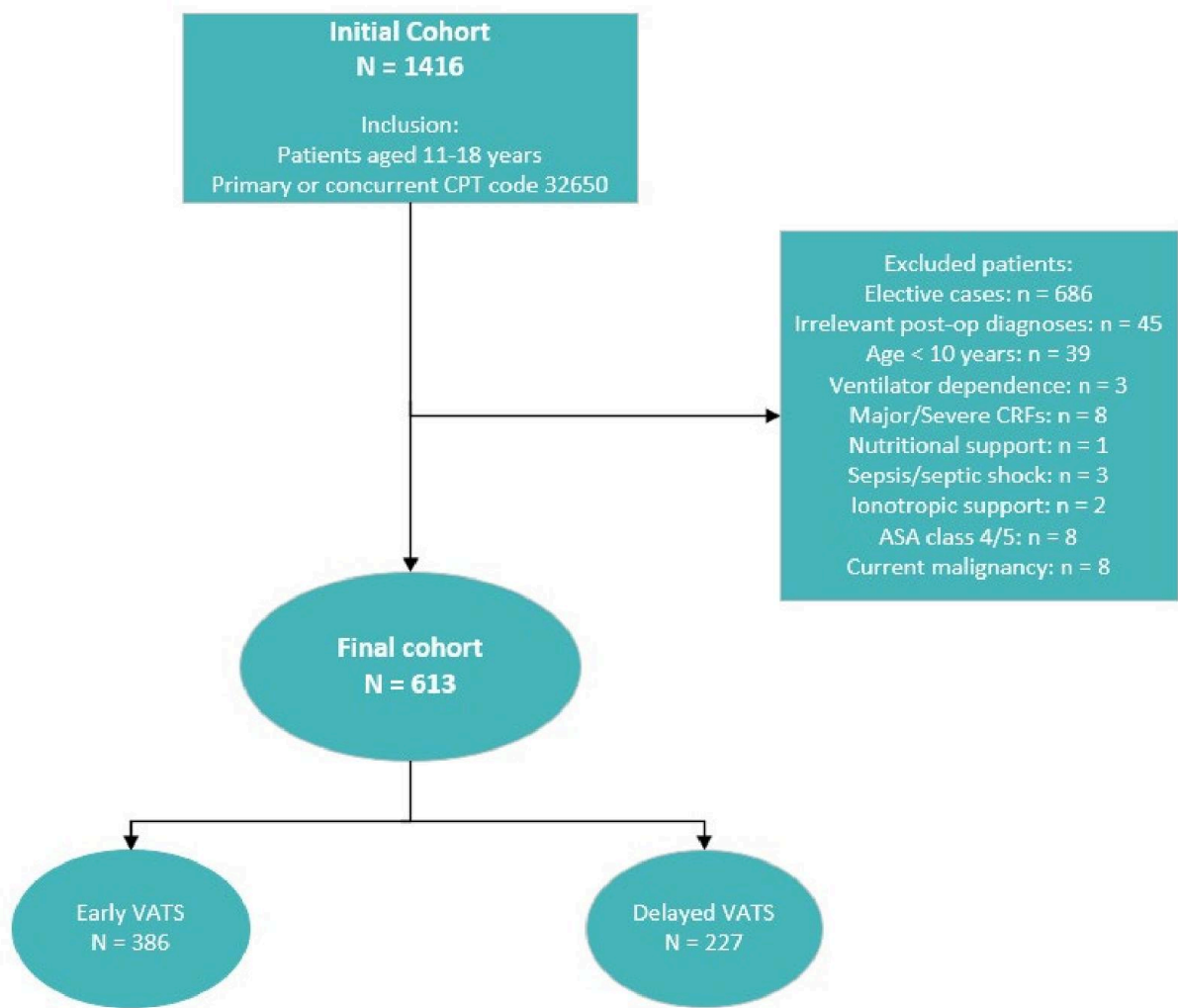
The data that support the findings of this study are available from the American College of Surgeons (ACS) NSQIP-Pediatric Participant Use Data File. These are not publicly available and were obtained under license, requiring a restricted data use agreement. The specific cohorts analyzed can be recreated by following the user guides provided by the ACS.

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Figures

Figure 1: Patient inclusion flow diagram



CPT = Current Procedural Terminology, CRF = cardiac risk factors, ASA = American Society of Anesthesiologists, VATS = video-assisted thoracoscopic surgery

Figure 1

See image above for figure legend

Figure 2: Annual trends in (≤ 1 day) versus delayed (> 1 day) video-assisted thoracoscopic surgery (VATS) delayed. Cochran-Armitage Test $p = 0.92$.

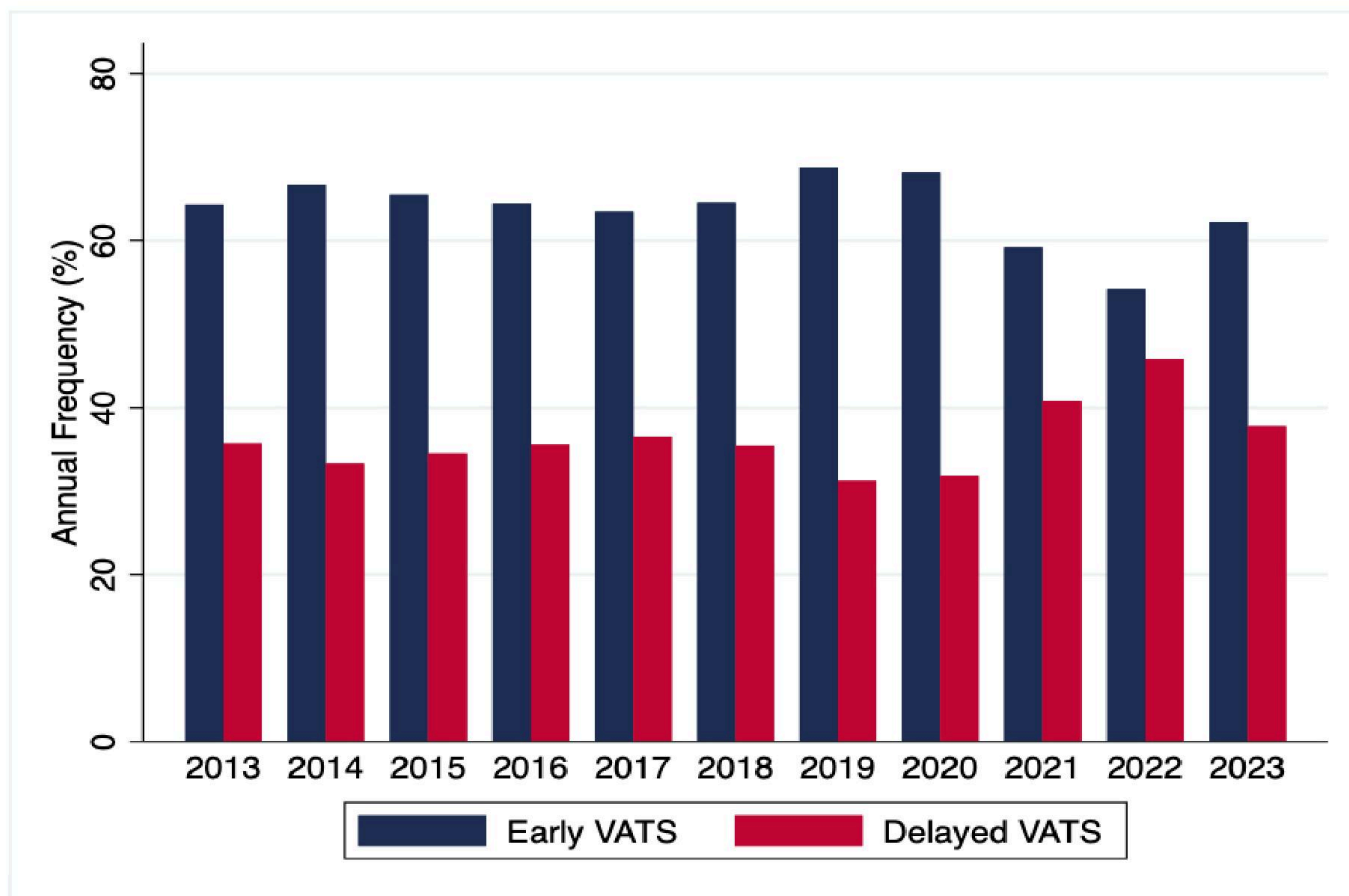


Figure 2

See image above for figure legend

Supplementary Files

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