Journal of Pediatric Surgery 56 (2021) 43–46

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Outcomes following adoption of a standardized protocol for abscess drain management in pediatric appendicitis☆

Lindsay M. Eysenbach [a], Michael G. Caty [a], Emily R. Christison-Lagay [a], Robert A. Cowles [a], Brian Dillon [b], Thomas Robin Goodman [b], Doruk E. Ozgediz [a], David H. Stitelman [a], Daniel G. Solomon [a,*]

[a] Yale School of Medicine, Division of Pediatric Surgery, Department of Surgery, New Haven, CT
[b] Department of Radiology and Biomedical Imaging, New Haven, CT

ARTICLE INFO

Article history:
Received 5 September 2020
Accepted 22 September 2020

Key words:
Appendicitis
Appendiceal abscess
Drain study

ABSTRACT

Background/purpose: Though evidence-based clinical pathways for the diagnosis and treatment of pediatric appendicitis have been established, protocols guiding management of percutaneous abscess drains are lacking. We hypothesized a drain management protocol utilizing drain output and clinical factors instead of fluoroscopic drain studies would reduce interventional radiologic procedures without adversely impacting clinical outcomes.
Methods: A standardized protocol was uniformly adopted at a tertiary-care children's hospital in April 2016. A retrospective chart review included all cases of appendicitis requiring abscess drainage by interventional radiology three years pre- and postprotocol implementation.
Results: Fifty-eight patients (preprotocol = 39, postprotocol = 19) underwent percutaneous abscess drainage, of whom 52 (preprotocol = 34, postprotocol = 18) required a drain. Baseline demographics and clinical presentation were similar across groups. Following protocol implementation, total number of IR procedures decreased from 2.4 to 1.3 per patient ($p = 0.004$). There was no significant difference in the number of postprocedure diagnostic imaging studies, readmissions, or inpatient days, and there was a trend towards a decrease in number of drain days (10.7 to 5.7, $p = 0.067$).
Conclusion: A standardized protocol for management of abscess drains for complicated appendicitis reduced the number of IR procedures without a negative impact on clinical outcomes or increase in alternative imaging studies. This approach may decrease radiation exposure, anesthetic administration, and resource utilization.
Type of study: Treatment study (retrospective comparative study).
Level of evidence: Level III.

Complicated appendicitis is a common presentation of appendicitis in children, and is associated with a three-fold increase in length of stay and readmission rates, as well as nearly double the costs when compared to nonperforated appendicitis [1]. Despite its frequency, significant practice variation exists in clinical management [1–3]. However, clinical practice guidelines which standardize the approach to clinical management, including timing of appendectomy, abscess drainage, and antibiotic coverage, can reduce resource utilization without an adverse effect on clinical outcomes [4–7].

Image-guided percutaneous drainage with or without drain placement is an established therapeutic option for management of simple intraabdominal and pelvic abscesses [8–11], including in a pediatric population [12,13]. Clinical outcomes are improved with abscess drainage in addition to antibiotic use in treatment of abscesses in the setting of pediatric appendicitis [14]. Thus, percutaneous abscess drainage by interventional radiologists is typically included in standardized management pathways for complicated appendicitis [5–7].

Despite the incorporation of indications for percutaneous abscess drainage into practice guidelines, to our knowledge protocols for management of abscess drains do not exist. In an adult population with intraabdominal or pelvic abscesses, repeat imaging such as CT scan or drain checks under fluoroscopy are often employed to assess for persistence of abscess cavity [15,16]. Alternative approaches to drain removal include monitoring for clinical signs of improvement (e.g. normothermia for >48 h) and removal after a decrease in drain output, typically defined as less than 10–20 cc/day [13]. Unfortunately, evidence guiding this approach is lacking; indeed, the American College of Radiology practice guidelines regarding percutaneous abscess drain placement do not address the question of proper timing of drain removal [17]. One retrospective analysis in adults suggested that a sinogram may reduce the risk of abscess recurrence [18]. A second study in adults with intraabdominal abscesses of diverse etiologies demonstrated that the majority (23/26) of

☆ *How this paper will improve care: The adoption of a protocolized pathway for drain management for appendiceal abscesses, where drain removal is determined by the child's clinical status and drain output, resulted in fewer drain days and fluoroscopic drain studies without increasing length-of-stay or readmissions.*

* Corresponding author at: Division of Pediatric Surgery, Department of Surgery, Yale School of Medicine, PO Box 208062, New Haven, CT 06520-8062. Tel.: +1 203 785 2701.
E-mail address: Daniel.Solomon@yale.edu (D.G. Solomon).

https://doi.org/10.1016/j.jpedsurg.2020.09.050
0022-3468/

patients with postappendectomy abscesses had full abscess resolution on initial imaging, suggesting that imaging may not be indicated as it is unlikely to change drain management [19].

In our institution, we adopted a standardized approach to drain management in the children with complicated appendicitis treated with percutaneous abscess drainage by interventional radiology. We hypothesized that protocol implementation would reduce the number of interventional radiology procedures without an adverse effect on clinical outcomes in this cohort.

1. Materials and methods

This study was conducted as part of the quality improvement process, and with approval from the institutional human investigations committee (HIC) (#2000026650).

1.1. Study population

All children younger than 18 years of age with perforated appendicitis who presented to the division of pediatric surgery at an academic medical center with 5 board certified attending pediatric surgeons between April 2013 and August 2019 and required percutaneous abscess drainage were included in the study. Patients who underwent upfront appendectomy and developed an abscess postoperatively, as well as patients who presented with an abscess and underwent initial drainage followed by interval appendectomy, were included in the study. The decision to undergo upfront versus interval appendectomy was at the discretion of the attending surgeon and was made based on duration of symptoms and the presence or absence of an abscess collection at the time of presentation. The patient population included both children who had a drain left in place and those who had percutaneous abscess drainage without drain placement at the discretion of the interventional radiologist. Not all patients had a drain placed within the initial hospitalization.

1.2. Protocol adoption

A standardized protocol for drain removal was developed collaboratively between the divisions of pediatric surgery and interventional radiology and uniformly adopted by both groups in April 2016. The protocol advocated for drain removal if the patient was afebrile and clinically well following 48 h with less than 20 cc per day drain output (Fig. 1).

1.3. Data collection

Demographic, surgical and interventional radiological data were extracted from the institutional electronic medical record. Data were collected on number and type of interventional radiology procedures related to abscess drainage as well as diagnostic ultrasound and CT studies obtained after abscess drainage. Clinical outcome variables included total hospital length of stay, total number of days with a drain in place, and readmissions and ED visits within 90 days of percutaneous abscess drainage.

1.4. Statistical analysis

Dichotomous measures were assessed with χ^2 test. For continuous variables, a t-test was used when data were normally distributed. When data were not normally distributed, the Wilcoxon rank sum test was used. All tests were 2-tailed using the cutoff of p value less than 0.05 for statistical significance. All analyses were conducted using Stata/IC 13.1 (StataCorp).

2. Results

2.1. Baseline population characteristics

58 patients (39 preprotocol, 19 postprotocol) who had interventional radiology procedures for percutaneous drainage and appendiceal abscess were identified. Preprotocol and postprotocol groups were similar in terms of demographics as well as white blood cell (WBC) count and duration of symptoms at presentation (Table 1). Thirteen of 39 patients (33.3%) in the preprotocol group underwent upfront appendectomy versus 9 of 19 (47.4%) in the postprotocol group ($p = 0.301$). In 34 patients in the preprotocol group (87.2%) an interventional radiologist left a drain in place, compared to 18 (94.7%) in the postprotocol group; the remaining children underwent aspiration without drain placement. In the preprotocol group, 47% of patients had their drains removed in the outpatient setting (clinic or IR). Postprotocol, 22% of patients had their drains removed in the outpatient setting.

2.2. IR procedures and diagnostic studies

Following implementation of the drain removal protocol, the number of IR procedures per patient decreased from 2.4 preprotocol to 1.3 postprotocol ($p = 0.004$) (Table 2). The largest decrease was seen in CT-guided procedures (0.7 to 0.2 per patient, $p = 0.001$); a trend towards fewer fluoroscopic-guided procedures was also noted (1.5 to 0.7 per patient, $p = 0.067$). The number of ultrasound-guided procedures showed a trend towards increasing (0.1 to 0.3 per patient, $p = 0.09$). There was no change in the number of postprocedure diagnostic ultrasounds (1.2 to 1.0 per patient, $p = 0.356$) or CT studies (0.3 to 0.3 per patient, $p = 0.722$).

2.3. Clinical outcomes

Among all study patients, the total number of drain days decreased by half in the pre- versus postprotocol group, though this finding did not reach the threshold of $p < 0.05$ (10.7 to 5.7 days per patient, $p = 0.067$) (Table 2). When patients for whom no drain was left in place were excluded from the analysis, the decrease in drain days was statistically significant (12.2 to 6.1 days per patient, $p = 0.008$) (Table 3). There was no significant difference in the total number of hospital days, readmissions, or ED visits between groups (Table 2). There were no differences in the duration of drain days within the pre- and postprotocol groups when comparing those who underwent upfront versus interval appendectomy. There were no deaths in either cohort.

3. Discussion

These data demonstrate a significant decrease in interventional radiology procedures following the implementation of a standardized protocol for drain management. Simultaneously, there was no significant difference in measured clinical outcomes or postprocedure diagnostic imaging studies following protocol adoption. Adoption of this protocol was associated with a 53.8% reduction in drain days among all patients who underwent intervention for their appendiceal abscesses and a 49.5% reduction in drain days when patients who only required aspiration were excluded from the analysis. These results are consistent with findings from an adult population suggesting that fluoroscopic drain checks may not be necessary to guide drain removal after appendiceal abscesses [19]. Additionally, the risks associated with fluoroscopic drain checks are less significant in an adult population for whom ionizing radiation poses a lower risk and anesthetics are typically not required.

While direct measures of anesthetic exposure, radiation dose, and cost were not obtained in this study, the reduction in IR procedures without a concomitant increase in alternative imaging studies suggests reduced patient exposure to ionizing radiation and anesthetics. While the radiation associated with a fluoroscopic drain study is quite low,

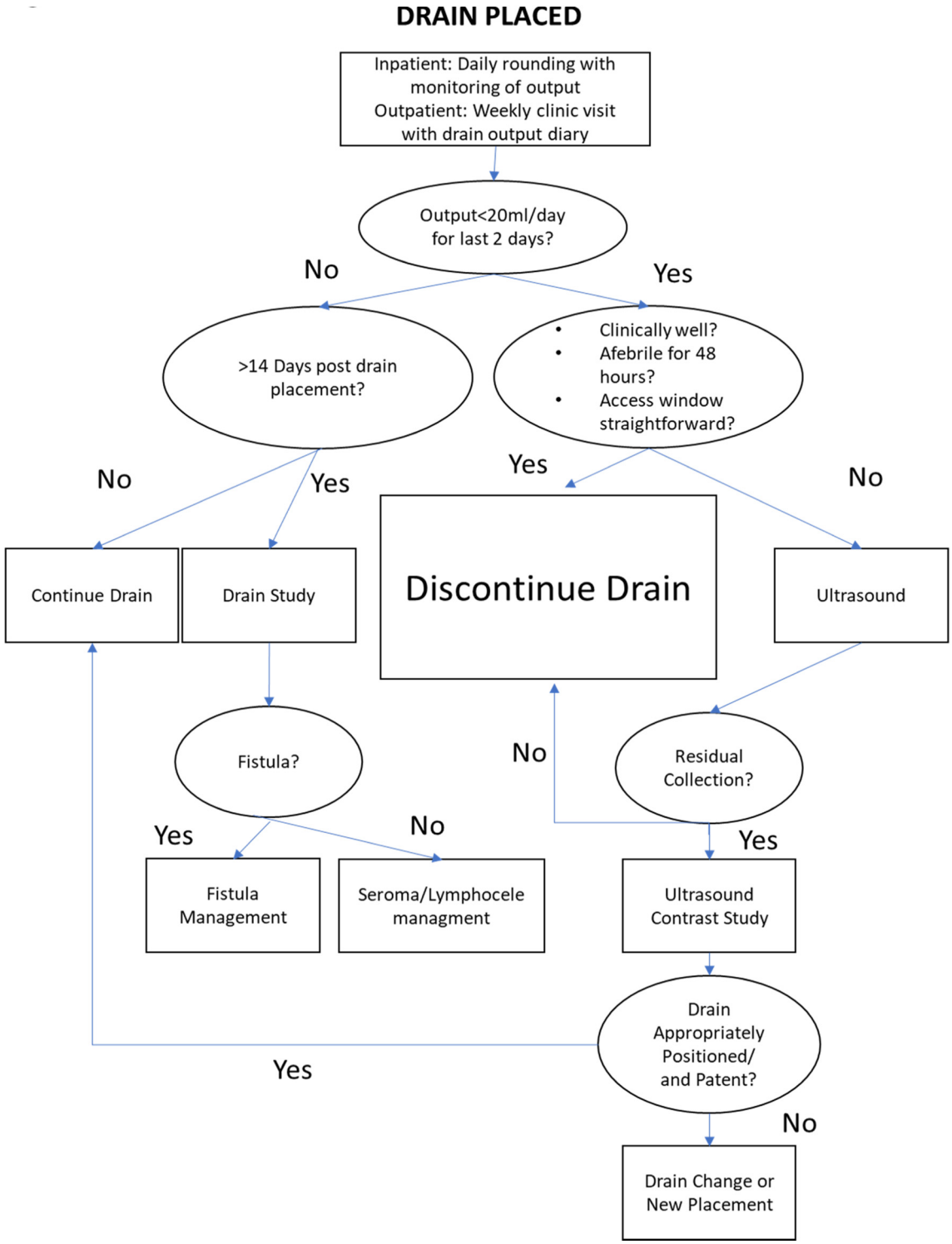

Fig. 1. Protocol flowchart.

children are more sensitive to radiation than adults [20] and effects of radiation exposure can be cumulative [21,22]; avoiding unnecessary drain studies represents one avenue to reduce cumulative lifetime exposure. Additionally, while drain checks can often be performed with minimal or no sedation in a compliant adult, young children may be unable to comply with the procedure without sedation. Finally, reducing the number of fluoroscopic drain checks reduces resource utilization and costs associated with abscess management.

This study was a retrospective analysis and thus did not control for other changes in management that may have occurred contemporaneously to protocol implementation. For example, during this time period there were an increase in initial drain placement under ultrasound guidance and a concomitant decrease in initial CT-guided placement. While this is unlikely to account for changes in drain management, this does highlight that there may have been additional practice changes in patient management that affected clinical outcomes that were not considered as part of this analysis. Similarly, though not statistically significant, a greater proportion of patients had their drains removed in the outpatient setting in the preprotocol group. It is not clear whether these patients would have met criteria

Table 1
Demographic and baseline clinical characteristics.

		Preprotocol	Postprotocol	
n		39	19	
		Mean ± st dev		p-value
Age (years)		10.3±4.3	9.9±4.2	0.72
Weight (kg)		43.4±25.4	36.3±20.8	0.35
WBC Count (×1000/μl)		16.9±5.7	17.9±7.6	0.59
		N (%)		p-value
Sex	Male	24 (61.5)	8 (42.1)	0.16
	Female	15 (38.5)	11 (57.9)	
Ethnicity	Hispanic	11 (28.2)	5 (26.3)	
	Non-Hispanic	28 (71.8)	14 (73.7)	
Race	White	19 (48.7)	14 (73.7)	0.29
	Black	5 (12.8)	1 (5.3)	
	Asian	2 (5.1)	0 (0)	
	Other	13 (33.3)	4 (21.1)	
Payer status	Medicaid	19 (48.7)	7 (36.8)	0.50
	Private	19 (48.7)	12 (63.2)	
	Other	1 (2.6)	0 (0)	
Duration of symptoms	≤48 h	8 (20.5)	2 (10.5)	0.35
	>48 h	31 (79.5)	17 (89.5)	
Diagnostic ultrasound	Ultrasound	31 (79.5)	4 (21.1)	0.96
	No ultrasound	8 (20.5)	15 (78.9)	
Diagnostic CT	CT	28 (71.8)	14 (73.7)	0.88
	No CT	11 (28.2)	5 (26.3)	
Perforation on imaging	No	4 (10.3)	4 (21.1)	0.38
	Microperforation	4 (10.3)	0 (0)	
	Perforation	7 (17.9)	3 (15.9)	
	Abscess	24 (61.5)	12 (63.2)	
Timing of appendectomy	Upfront	13 (33.3)	9 (47.4)	0.30
	Interval	26 (66.7)	10 (52.6)	
Drainage type	Drain	34 (87.2)	18 (94.7)	0.38
	No drain	5 (12.8)	1 (5.3)	
Location of drain removal	Inpatient	18 (52.9)	14 (77.8)	0.13
	Outpatient	16 (47.1)	4 (22.2)	

for drain removal as an inpatient under the protocol, but this likely contributed to the greater number of drain days.

Additionally, while this study includes six years of data from our institution, the overall cohort of patients with appendicitis complicated by abscess formation is still relatively small. Thus, it is possible that there are changes in clinical outcomes after protocol implementation that our study was not adequately powered to demonstrate.

4. Conclusion

The results of this study suggest that a standardized protocol for management of percutaneous drains placed by interventional radiology can effectively reduce the number of interventional radiology procedures children receive without an adverse effect on clinical outcomes. Thus, physicians may consider incorporating similar drain management protocols into existing clinical practice guidelines for complicated pediatric appendicitis. More research is needed to evaluate optimal drain management for intraabdominal abscesses in other populations.

Table 2
Clinical outcomes.

	Preprotocol	Postprotocol	
	#/patient ± st dev		p-value
Total IR procedures	2.4±1.6	1.3±0.5	0.004
CT-guided procedures	0.7±0.5	0.2±0.2	0.001
Fluoroscopic-guided procedures	1.5±1.5	0.7±0.7	0.067
Ultrasound-guided procedures	0.1±0.3	0.3±0.5	0.09
Diagnostic ultrasound	1.2±0.4	1.1±1.6	0.36
Diagnostic CT	0.3±0.5	0.3±0.6	0.72
Drain days	10.7±9.5	5.7±3.9	0.067
Hospital days	9.6±4.9	9.8±4.8	0.8
# Readmissions	0.5±0.5	0.3±0.5	0.24
# ED visits	0.6±0.7	0.5±0.7	0.58
90-day mortality	0	0	1

Table 3
Clinical outcomes, excluding aspirations.

	Preprotocol	Postprotocol	
n	34	18	p-value
	#/patient ± st dev		
Total IR procedures	2.6±1.6	1.3±0.5	0.001
Drain days	12.2±9.3	6.1±3.7	0.008
Hospital days	9.9±4.9	10.1±4.8	0.77
# Readmissions after IR procedure	0.5±0.7	0.3±0.7	0.28

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2020.09.050.

References

[1] Newman K, Ponsky T, Kittle K, et al. Appendicitis 2000: variability in practice, outcomes, and resource utilization at thirty pediatric hospitals. J Pediatr Surg. 2003;38(3):372–9.
[2] Morrow SE, Newman KD. Current management of appendicitis. Semin Pediatr Surg. 2007;16(1):34–40.
[3] Muehlstedt SG, Pham TQ, Schmeling DJ. The management of pediatric appendicitis: a survey of North American pediatric surgeons. J Pediatr Surg. 2004;39(6):875–9.
[4] Russell WS, Schuh AM, Hill JG, et al. Clinical practice guidelines for pediatric appendicitis evaluation can decrease computed tomography utilization while maintaining diagnostic accuracy. Pediatr Emerg Care. 2013;29(5):568–73.
[5] Knott EM, Gasior AC, Ostlie DJ, et al. Decreased resource utilization after initiation of institutional pathway for caring for perforated appenciditis. . 2013;48(6):1395–8.
[6] Slusher J, Bates CA, Johnson C, et al. Standardization and improvement of care for pediatric patients with perforated appendicitis. J Pediatr Surg. 2014;49(6):1020–4.
[7] Willis ZI, Duggan EM, Bucher BT, et al. Effect of a clinical practice guideline for pediatric complicated appendicitis. JAMA Surg. 2016;151(5):e160194.
[8] van Sonnenberg E, Wittich GR, Goodacre BW, et al. Percutaneous abscess drainage: update. World J Surg. 2001;25(3):362–9.
[9] van Sonnenberg E, Mueller PR, Ferrucci JT. Percutaneous drainage of 250 abdominal abscesses and fluid collections. Part I: results, failures, and complications. Radiology. 1984;151(2):337–41.
[10] Levin DC, Eschelman D, Parker L, et al. Trends in use of percutaneous versus open surgical drainage of abscesses. Journal of the American College of Radiology. 2015;12(12 Pt A):1247–50.
[11] Jaffe TA, Nelson RC. Image-guided percutaneous drainage: a review. Abdominal Radiology. 2016;41(4):629–36.
[12] McNeeley MF, Vo NJ, Prabhu SJ, et al. Percutaneous drainage of intra-abdominal abscess in children with perforated appendicitis. Pediatr Radiol. 2012;42(7):805–12.
[13] Gervais DA, Brown SD, Connolly SA, et al. Percutaneous imaging-guided abdominal and pelvic abscess drainage in children. Radiographics. 2004;24(3):737–54.
[14] Luo CC, Cheng KF, Huang CS, et al. Therapeutic effectiveness of percutaneous drainage and factors for performing an interval appendectomy in pediatric appendiceal abscess. BMC Surg. 2016;16(1):72.
[15] Gee MS, Kim JY, Gervais DA, et al. Management of abdominal and pelvic abscesses that persist despite satisfactory percutaneous drainage catheter placement. Am J Roentgenol. 2010;194(3):815–20.
[16] Charles HW. Abscess drainage. Semin Intervent Radiol. 2012;29(4):325–36.
[17] Lorenz J, Al-Refaie WB, Cash BD, et al. ACR appropriateness criteria radiologic management of infected fluid collections. J Am Coll Radiol. 2015;12(8):791–9.
[18] Springer JE, D'ourmouras AG, Nair S, et al. Does imaging before percutaneous drain removal affect rates of intra-abdominal abscess recurrence? Journal of Surgical REsearch. 2018;232:408–14.
[19] Brac B, Sabbagh C, Robert B, et al. Natural history of percutaneous drainage of postoperative patients after colorectal surgery: in which patients can follow up imaging be dispensed with before drain removal? Abdominal Radiology. 2019;44(3):1135–40.
[20] Kutanzi KR, Lumen A, Koturbash I, et al. Pediatric exposures to ionizing radiation: carcinogenic considerations. Int J Environ Res Public Health. 2016:13(11).
[21] Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012;380(9840):499–505.
[22] Fabritius G, Brix G, Nekolla E, et al. Cumulative radiation exposure from imaging procedures and associated lifetime cancer risk for patients with lymphoma. Sci Rep. 2016;6:35181.