

**ΜΕΤΑΠΤΥΧΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΣΠΟΥΔΩΝ:
“ΕΛΑΧΙΣΤΑ ΕΠΕΜΒΑΤΙΚΗ ΧΕΙΡΟΥΡΓΙΚΗ,
ΡΟΜΠΟΤΙΚΗ ΧΕΙΡΟΥΡΓΙΚΗ ΚΑΙ ΤΗΛΕΧΕΙΡΟΥΡΓΙΚΗ”**

**ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ΙΑΤΡΙΚΗ ΣΧΟΛΗ**

ΔΙΠΛΩΜΑΤΙΚΗ ΕΡΓΑΣΙΑ

**ΘΕΜΑ: ΠΡΩΤΟΠΑΘΗΣ ΣΥΣΤΡΟΦΗ ΕΠΠΛΟΟΥ ΣΤΑ ΠΑΙΔΙΑ ΤΗΝ ΕΠΟΧΗ
ΤΗΣ ΛΑΠΑΡΟΣΚΟΠΗΣΗΣ**

ΜΕΤΑΠΤΥΧΙΑΚΟΣ ΦΟΙΤΗΤΗΣ:

ΑΛΕΞΟΠΟΥΛΟΣ ΒΑΣΙΛΕΙΟΣ

A.M.: 20201292

ΕΠΙΒΛΕΠΩΝ: ΚΑΘΗΓΗΤΗΣ κ. ΔΗΜΗΤΡΟΥΛΗΣ ΔΗΜΗΤΡΙΟΣ

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MASTER THESIS

**PRIMARY OMENTAL TORSION IN CHILDREN IN THE LAPAROSCOPY
ERA: WHAT HAVE WE LEARNED SO FAR?**

**POSTGRADUATE STUDENT:
ALEXOPOULOS VASILEIOS**

A.M.: 20201292

SUPERVISOR: PROFESSOR DIMITROULIS DIMITRIOS

ATHENS

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Περίληψη

Εισαγωγή/Σκοπός: Η πρωτοπαθής συστροφή επιπλόου είναι μια ασυνήθιστη, μιμούμενη την σκωληκοειδίτιδα και άλλες παθήσεις οξείας κοιλίας. Συχνά διαφεύγει της διάγνωσης κατά την απεικονιστική εξέταση ή κατά την συμβατική ανοικτή λαπαροτομία. Σκοπός μας ήταν να αξιολογήσουμε την επίδραση της λαπαροσκόπησης στις διάφορες όψεις αυτής της οντότητας, συμπεριλαμβανομένης της επίπτωσης, της διάγνωσης και της θεραπείας.

Υλικό και Μέθοδος: Πραγματοποιήσαμε μια συστηματική ανασκόπηση, συμπεριλαμβανομένων των βάσεων δεδομένων PubMed και Scopus, χωρίς κανένα χρονικό περιορισμό, ακολουθώντας τις αρχές PRISMA. Συνολικά 16 άρθρα από τον Ιανουάριο του 2000 μέχρι τον Δεκέμβριο του 2023, που αντιστοιχούν σε 56 παιδιά με πρωτοπαθή συστροφή επιπλόου, πληρούσαν τα κριτήρια της έρευνας.

Αποτελέσματα: Η πρωτοπαθής συστροφή επιπλόου συσχετίστηκε με την παχυσαρκία. Τα συμπτώματα ήταν εντοπισμένα προς τη δεξιά κοιλία, συχνά σε σύγκριση με αυτά της οξείας σκωληκοειδίτιδας. Το προεγχειρητικό υπερηχογράφημα εμφάνισε χαμηλή διαγνωστική ακρίβεια, ενώ η αξονική τομογραφία διέγνωσε μόνο τα δύο τρίτα των περιπτώσεων. Σε όλους τους ασθενείς, η σκωληκοειδής απόφυση ήταν φυσιολογική.

Συμπέρασμα: Η λαπαροσκόπηση επηρέασε τόσο τη διάγνωση όσο και τη θεραπεία της πρωτοπαθούς συστροφής επιπλόου στα παιδιά. Η εύκολη πρόσβαση στην περιτοναϊκή κοιλότητα κατέστησε δυνατή τη διάγνωση περιπτώσεων που προηγουμένως είχαν λάβει εξιτήριο ως κοιλιακό άλγος αγνώστου αιτιολογίας. Σε συνδυασμό με την αυξημένη παιδική παχυσαρκία, επηρέασε επίσης την επίπτωση της πρωτοπαθούς συστροφής επιπλόου. Οι πρόσφατες θεωρίες παθογένεσης μπορεί να υποστηριχθούν καλύτερα σήμερα, καθώς η λαπαροσκόπηση παρέχει μια λεπτομερή όψη in situ και διευκολύνει τη συλλογή λιπώδους ιστού από το επίπλουν για μοριακή διερεύνηση. Η διαγνωστική αποτελεσματικότητα της λαπαροσκόπησης είναι ανώτερη από το υπερηχογράφημα και την αξονική τομογραφία. Τέλος, η αφαίρεση του ισχαιμικού επιπλόου είναι τεχνικά ευκολότερη σε σύγκριση με την εναλλακτική ανοικτή λαπαροτομία με όλες τις τεχνικές δυσκολίες έλξης ενός ευάλωτου αιμορραγικού ιστού μέσω μιας μικρής τομής

Λέξεις κλειδιά: Πρωτοπαθής συστροφή επιπλόου, Λαπαροσκόπηση, Λαπαροσκοπική χειρουργική, Κοιλιακό άλγος, Μείζων επίπλουν, Παιδιά

Abstract

Background/Aim: Primary omental torsion is uncommon, mimicking appendicitis and other acute abdominal pathologies. It often escapes diagnosis on imaging investigation or conventional open laparotomy. We aimed to evaluate the effect of laparoscopy on the various insights of this entity, including incidence, diagnosis, and treatment.

Materials and Methods: We performed a systematic review, including PubMed and Scopus databases, without time limit, following the PRISMA principles. A total of 16 articles from January 2000 to December 2023, corresponding to 56 children with primary omental torsion, complied with the research criteria.

Results: Primary omental torsion was associated with obesity. Symptoms were right abdomen oriented, often compared to those of acute appendicitis. Preoperative ultrasound displayed low diagnostic accuracy, while computerized tomography diagnosed only two thirds of cases. In all patients, the vermiform appendix was normal.

Conclusion: Laparoscopy affected both diagnosis and treatment of primary omental torsion in children. Easy peritoneal cavity access rendered possible the diagnosis of cases previously discharged as abdominal pain of unknown etiology. Combined with the increased pediatric obesity, it also affected primary omental torsion incidence. The recent pathogenetic theories may be better supported today, as laparoscopy provides a detailed view in situ, and facilitates harvesting of fat tissue from the omentum for molecular investigation. The diagnostic efficiency of laparoscopy is superior to ultrasonography and computerized tomography. Finally, the removal of the ischemic omentum is technically easier compared to the open laparotomy alternative with all the technical difficulties of traction of a vulnerable hemorrhagic tissue through a small incision.

Key Words: Primary omental torsion; Laparoscopy; Laparoscopic surgery; Abdominal pain; Greater omentum; Children

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Introduction

Omental pathology is uncommon, with a reported incidence of 1:600 appendectomies during a period of 20 years in Australia (1), and 1:800 appendectomies in 30 years in the United States (2). Bush was the first who described the idiopathic omental infarction in 1896 (3). Three years later, Eitel described the primary omental torsion (POT) as a cause of abdominal pain (4). Since then, approximately 400 patients with POT have been reported worldwide, with an age peak of 40-50 years, and with two thirds being males (5-7). POT incidence in the pediatric population is 0.1-0.5%, extracted mostly through surgical intervention for acute abdominal pain, attributed to possible appendicitis (8-12).

The omentum is the main defensive organ of the abdominal cavity, adopting an adhesive behavior to seal an impaired area (13). Increase of the omental blood flow and expansion of the omental stromal tissue occur as a response to stimulation (14,15). Cells which express stem cell markers, inflammatory, and chemotactic factors, are produced (16-18). The activated stromal cells engraft onto the irritated sites and lead to the recruitment of inflammatory cells within the peritoneal cavity. The result is the formation of adhesive bridges (14,19,20).

The omentum may rotate along the axis of the distal right epiploic artery (2), either with a clockwise or counterclockwise direction (21,22). Congenital developmental abnormalities and variations (bifid omentum, tongue-like projections, redundant omental veins, local fat accumulation) may facilitate torsion (23-27). The right part of the omentum, which is larger, heavier, and with independent mobility, is affected more frequently (22,28). The aggressive omental behavior in association with anatomical and physiological factors (acute alteration of posture, digestion of excessive food, visceral fat associated inflammation) favor torsion, infarction, and finally necrosis.

POT symptoms are nonspecific. They mainly mimic appendicitis while older children and adults may also present with symptoms indicative of cholecystitis, perforation or peptic ulcer, and ovarian torsion (29,30). During the early phases of torsion, traction of the omental root occurs, causing initially periumbilical pain, or pain at the xiphoid process (30). As congestion, ischemia and necrosis of the rotated segment develop, the pain adopts the characteristics of appendicitis, in many instances without the typical symptoms of appendiceal bacterial infection such as nausea, vomiting, fever, tension, emergency, or diarrhea (31). Furthermore, the progress of the symptoms is slower compared to appendicitis (31). The clinical differential diagnosis in children may also include Meckel's diverticulitis, mesenteric lymphadenitis, gastroduodenitis, or Crohn's disease (22).

Diagnosis of POT may be performed by ultrasonography (US) and computerized tomography (CT) (32-35).
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Magnetic resonance imaging (MRI) has been used sporadically as well (36). Omental infarction imaging was

first described by Puylaert (37). US nonspecific results may include free fluid in the pelvis or the right iliac fossa, or a hyperechoic mesentery (38,39). The sonographic criterion for the diagnosis of omental infarct is the identification of an oval hyperechoic mass, adherent to the abdominal wall with a hypoechoic rim, located mainly at the right side of the abdomen, with the presence of a normal appendix (40,41). In the CT, the density of the omental mass is not different from that of the abdominal wall fat (30). The location of a fatty soft tissue structure between the colon and the rectus abdominis sheath has been considered specific for the diagnosis with CT (30,40). The infarcted omentum is delineated as a fatty mass immediately deep to the parietal peritoneum, with secondary thickening and inflammation of the overlying anterior abdominal wall (24,37,42,43). The presence of a vascular pedicle, and the whirl of the omentum are characteristic signs (30). A variety of diseases are included in the imaging differential diagnoses of omental torsion, such as mesenteric panniculitis, lipoma, liposarcoma, teratoma, angiomyolipoma, epiploic appendagitis, gossypiboma and tumours containing fat (44). Operative management is the gold standard treatment method. With the advent of laparoscopy, both diagnosis and treatment of POT have been affected. The first two reports of POT laparoscopic treatment in adults were published by Chung et al., and Gassner et al., (45,46) while Gul et al., reported the first pediatric laparoscopic excision of necrotic omentum after POT, in a case series which included a 14-years-old boy (26).

In this systematic review, we aimed to investigate the impact of laparoscopy on the diagnosis and treatment of POT in children and discussed issues such as pathogenesis and clinical presentation of this uncommon entity. We also aimed to compare the diagnostic efficiency of laparoscopy with that of US and CT, and its therapeutic efficiency compared to conservative treatment and open laparotomy in this easy to treat morbidity, however until recently often escaping diagnosis.

Materials and Methods

We performed a systematic literature review with the following criteria for article types: original articles, case studies, case series, articles obtained in full text, articles in English, and articles in humans. No time limit was set for articles related to their research or publication. The databases used were PubMed and Scopus. The keyword combinations included [omental torsion], [omental infarct], [primary omental torsion], [children], [pediatric], [laparoscopic surgery], [laparoscopy].

The principles of the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) methodology were used for the analysis of the retrieved information (47,48). A total of 16 articles published during a period of 23 years (January 2001 - December 2023) were considered suitable for inclusion in the study (Figure 1, Table I). The chi-square test was employed to determine the correlation between qualitative

independent variables. The statistical analysis was performed with the SPSS Statistical Software Package version 25 (IBM Corp., Armonk, NY, USA). The threshold for statistical significance was defined as $p < 0.05$.

Results

The study population included 56 children with a predominance of boys ($n=44$, 78.5%) (Table I). The gender of two patients was not reported in one study (49). The age range of the patients was 4-16 years. All articles were case reports or case series. The largest series from a single center included 17 patients (30).

The main clinical symptom which was present in every child with POT was abdominal pain. The initial distribution of pain involved the right lower ($n=33$ patients, 58.9%), right middle ($n=8$, 14.3%), right upper ($n=7$, 12.5%), and left lower abdomen ($n=2$, 3.5%), the epigastrium ($n=3$, 5.3%), and the periumbilical ($n=3$, 5.3%) region. Few patients had gastrointestinal symptoms such as nausea ($n=9$, 16.0%), vomiting ($n=13$, 23.2%), and clinical signs such as rebound tenderness ($n=6$, 10.7%), and abdominal muscle guarding ($n=21$, 37.5%). It is of note that there were studies which mentioned the presence of a good appetite regardless of the presence of pain (9,50). Low grade fever was reported in 15 (26.7%) patients. White blood cell count was moderately elevated in 20 (35.7%) patients, while c-reactive protein (CRP) was elevated in 21 (37.5%). A total of 46 (82.1%) patients were characterized as overweight or obese.

The outcomes of preoperative radiological investigation are shown in Table II. Preoperative US was performed in 44 (78.5%) patients. However, its diagnostic accuracy was low, as an inflammatory mass was diagnosed in only 5/44 (11.3%) patients. The most commonly reported outcome was the presence of free fluid in the peritoneal cavity ($n=8$, 18.1%). CT examination was conducted in 33 (58.9%) patients with a positive diagnosis in 24/33 (72.7%). MRI was recruited once, with a positive diagnostic outcome (36) (Table II).

All patients of the study were submitted to laparoscopy. The main finding was a mass corresponding to the rotated, infarcted and gangrenous omentum. It was either pending free in the peritoneal cavity or adhered to various structures in the abdomen, i.e., the anterior or right abdominal wall, the lower abdomen or higher at the hypochondrium, near the hepatic margin, behind the liver, or at a right lumbar location. It was also adhered to the ascending colon, the cecum, even the sigmoid colon (21). Anatomic redundancy of the rotated right omental portion was mentioned (51). A total of 720° was the most severe twist described (22). The presence of free serosanguineous fluid in the abdominal cavity was characteristic (52). The vermiform appendix was found without inflammation in all 56 children. Except for one study (30) who reported a mean postoperative hospital stay of five days, the patients were discharged from the first to the third postoperative day. No significant postoperative complications were reported. One patient presented relapse of torsion after eight months (30).

Discussion

Though the outcomes of this systematic review were obtained from a limited study population, interesting insights on POT were obtained. It has been rendered obvious that laparoscopy created new perspectives which affected epidemiology, pathogenesis, diagnosis, and treatment.

How laparoscopy affected POT incidence

POT incidence has increased during the last twenty years. While older studies on large numbers of children reported an incidence of one case of omental infarction in 800 operations (2) for possible appendicitis, in more recent series the incidence was one in 275 operations (11). Moreover, Valioulis et al., reported two patients with primary omental torsion among 54 exploratory laparoscopies for acute abdominal pain (28), while Jukic et al., reported four cases among 244 children who underwent negative appendectomy (53). It is of note that by providing in the PubMed database the key words “primary omental torsion” and “children”, during the period 1950-2000 there is an outcome of 38 articles found on POT (rate 0.7 per year), while between 2001 and 2023, actually a half-time period, the rate of studies was doubled, (33 articles, rate 1.4 per year).

Increased childhood obesity is associated with increased POT incidence (7,11,39,40). Furthermore, during the same period, the advent of laparoscopy rendered POT diagnosis more effective, favoring the balance between diagnosed and undiagnosed cases towards the first. Open laparotomy presents limited exposure of the peritoneal cavity (9), often accessing the ischemic omentum accidentally, during an excision of a normal appendix. This may result in the loss of undiagnosed cases of omental pathology. Presumably, as pediatric surgeons become more familiar with the use of the fine laparoscopic means, and as more pediatric centers adopt minimal invasive techniques, more cases previously labeled as abdominal pain of unknown origin on hospital discharge will be diagnosed properly.

Association of laparoscopy with insights on POT pathogenesis

Congenitally anomalous fragile blood supply to the right lower portion of the greater omentum renders this region easier to infarction (53). Venous engorgement after heavy meals or venous elongation produced by excessive weight of the greater omentum have been proposed as risk factors, since there is a higher prevalence of the syndrome in the obese population (54). Excessive gravitational traction is exerted by a larger omentum as well (24,55). In these patients, the increased fat deposition may also outstrip the blood supply to the developing omentum. It has been proposed that not only the total amount of omental fat but the irregular distribution in obesity leads to the development of torsion (50). Children older than three years present increased fat deposition
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in the developing omentum in association with growth, which may be considered as a major predisposing factor

(11). Furthermore, the greater accumulation of omental fat in males compared to females, may be associated with POT preponderance in obese boys (56). By the advent of laparoscopy, the theories described herein are easier to be supported, as the panoramic view of the peritoneal cavity renders the diseased omentum visible in situ.

It is of note that the findings of this systematic review are in accordance with the relevant literature, as the younger patients were four-year-old, and most of them belonged to the spectrum of obesity. Moreover, POT was four times more common in the boys of the study, compared to girls. A total of 82.1% children were found obese, verifying the association of obesity and torsion probability. It is obvious that laparoscopy offers in particular in obese patients a more convenient and less traumatic access to the diagnosis and treatment of POT, compared to a constricted access through a small incision in a thick abdominal wall.

Sudden alteration of the abdominal position and immediate increase of the abdominal pressure may induce rotation of the omentum (11). Mainly in children with the characteristics described previously, overeating, intestinal hyperperistalsis, overextension, sudden changes of body position, excessive exercise, and trauma may trigger omental torsion (25,27,57). We infer that such small torsions along the longitudinal axis may occur asymptomatic, or with mild symptoms such as recurrent moderate abdominal pain, affecting omental physiological reaction. Thus, in some cases a congestion and blood supply impairment, even small, may trigger the omental biological cataract of inflammation and adhesion. These conditions with a milder clinical presentation, may be definitively diagnosed with laparoscopy today.

We know that visceral fat is associated with the production of inflammatory response (58). The homeostasis of the visceral adipose regulatory T cell population, in the human omental fat, is a field of contemporary research. These cells play a critical role in controlling visceral fat inflammation by alleviating metabolic disease (58). However, this cell population is disrupted by obesity which exacerbates inflammation and metabolic abnormalities. Studies support that these cells are even lost in obesity (59). Maybe the answer to our question on POT pathophysiology lies in these fatty omental cells. We support that one more action during laparoscopic surgery should be tissue sample acquisition in situ, for molecular investigation, in collaboration with molecular biologists specialized in obesity.

Verification of clinical presentation outcomes by laparoscopy

The POT symptoms are dependent on the degree and duration of torsion (30). The pain is usually sudden on onset with progressive exacerbation (7,39,50,60). In approximately 90% of patients, the pain is located at the

right side of the abdomen (27,28). In the series of this review, most children (n=48, 85%) presented with a right abdominal distribution of symptoms.

Nausea and vomiting are encountered in 50% of POT patients (55). In the series of our review, nausea was reported in one out of ten patients, while one out of four patients presented with vomiting. POT has also been presented as a hip pain and limp (61). Patients with POT may not seem as ill as those with acute appendicitis. Children with omental infarction are constitutionally well, hungry, afebrile and without elevated white blood cell count. This accounts for the delay in seeking surgical evaluation (24). Finally, in this study the right abdominal preponderance of symptoms is verified, as well as the fact that patients with a good appetite were reported in our review (9,50).

The superiority of laparoscopy against US and CT as a diagnostic tool in POT

We must correlate the variability of the results with ultrasonography with two factors, both regarding the operator. The first is personal experience, ability and subjectivity. The ultrasound imaging findings are subtle and operator dependent (49). Secondly, we must not forget the operator's subjective tendency in diagnosing acute appendicitis. No operator starts a pediatric abdominal ultrasound having in mind that the certain patient might present an omental torsion, but the first asset of differential diagnosis is acute appendicitis. The overall diagnostic rate of omental torsion has been estimated at about 10% (62,63). CT has been proved to be the most accurate radiological diagnostic tool so far (30). Recently, Chen et al., reported a diagnostic accuracy of 70.59% in the largest series of POT cases in children reported in a single center (30).

US was accurate in 11.3% and CT in 72.7% in the study population of this review, where POT was confirmed with laparoscopy in 100% (Table II). In a statistical analysis performed in the study population of our review, CT proved to be a more reliable diagnostic tool compared to US, ($\chi^2=30.24441$, $p < 0.001$). Nevertheless, it missed one third of cases, which is a fair proportion. The diagnostic deficiency of both radiological methods renders laparoscopy a valuable tool not only from the aspect of therapy but also from that of diagnosis.

Practical operative benefits of laparoscopy

Conservative treatment with observation and supportive measures is an alternative option of management (32,49). It has been advocated when diagnosis is made with CT (49,64). Patients who benefit from this approach usually have localized moderate abdominal pain. It includes overnight observation, serial abdominal examinations, and continuous adjustment of the administered pain medications (49). In the absence of peritoneal signs, children with POT have been reported to be treated conservatively with complete resolution of abdominal pain. We must not forget that this is the point which in the past created cases of undiagnosed abdominal pain

who had a favorable conservative outcome in the absence of radiological diagnosis. This deficiency ends with the advent of laparoscopy.

Laparoscopy can be effectively and safely performed in children (50,65). The twisted omentum may be easily and safely excised laparoscopically. There were no major intraoperative or postoperative complications encountered in the research articles included in this review, and a rapid recovery with good cosmetic results was universally observed (50). Only one patient of the 56 of our systematic review, with relapse of torsion after eight months, might be considered as the only long-term complication (30).

A great advantage of laparoscopic surgery is the adaptation of trocar placement for the achievement of the best and easier performance (51,66). While in conventional laparotomy all the work must be done through a small incision with restrictive optical ability, it does not only render the possibility of misdiagnosis, but forces the surgeon to perform elaborate movements and manipulations either with instruments or with the fingers, especially in obese children. With laparoscopy, the trocars are placed after the localization of the lesion, with the most convenient result. Although removal of the intact lesion is the rule, segmental (piecemeal) removal has also been reported (45).

With laparoscopy, other common pathologies, such as the primary clinical target of acute appendicitis, secondary torsion, or infarction without torsion which presents similar radiological characteristics, were effectively diagnosed and treated (36,40,49). In the study population of this review, the treatment of the patients with the most serious clinical presentation who were initially treated conservatively, was switched to laparoscopic exploration (40,49).

A final comment should be made on the postoperative course and hospital stay. Although patients who were submitted to laparoscopy were those who presented more serious clinical symptoms and signs, their postoperative stay in hospital was short (67,68). Most of the patients in our review were discharged from hospital from the first to the third postoperative day. Delayed surgical or conservative treatment may lead to complications such as abdominal abscess, sepsis and adhesion formation (22,68).

Study limitations

The main limitation of the study is the small population outcome, as POT has been considered as a rare disease so far, and laparoscopy is actually a novel technique in children. However, we believe that in the next years, with the widespread performance of minimal invasive surgery, even robotic surgery in pediatric patients, the epidemiological indexes will be modified to more representative numbers. Finally, with the inclusion of articles only written in the English language, we may have excluded some interesting articles in other languages.

Conclusions

POT diagnosis in children has become easier with the advent of laparoscopy in pediatric surgery during the last twenty years. The identification of the twisted ischemic omentum is timely feasible, with minimal surgical tissue damage and early hospital discharge, together with a full inspection of the peritoneal cavity. The possibility of diagnosing different pathologies is more efficient as well. Although CT presents a certain accuracy, it may miss a fair number of cases of POT. Management is also easier, with the safe removal of the gangrenous omental tissue without the difficulty, stretching, and elaborative manipulations of conventional open surgery, through a small incision, frequently in an obese child. Finally, pathogenesis theories may be postulated more definitively with immediate visualization of the peritoneal cavity as a hall. Furthermore, targeted acquirement of in situ material for histopathological and molecular investigation will pour more light on the pathogenesis of the primary omental reaction that leads to torsion.

Conflicts of Interest

The Authors declare that they have no conflicts of interest or financial ties in relation to this study.

Authors' Contribution

VA and XS designed this study. Data collection and literature searches were performed by VA, XS, and AL. VA, XS, AL, CD, and DD performed the data analysis and interpretation. All researchers interpreted the data and contributed to the draft of the manuscript and figures. Finally, the paper was revised and approved by all authors.

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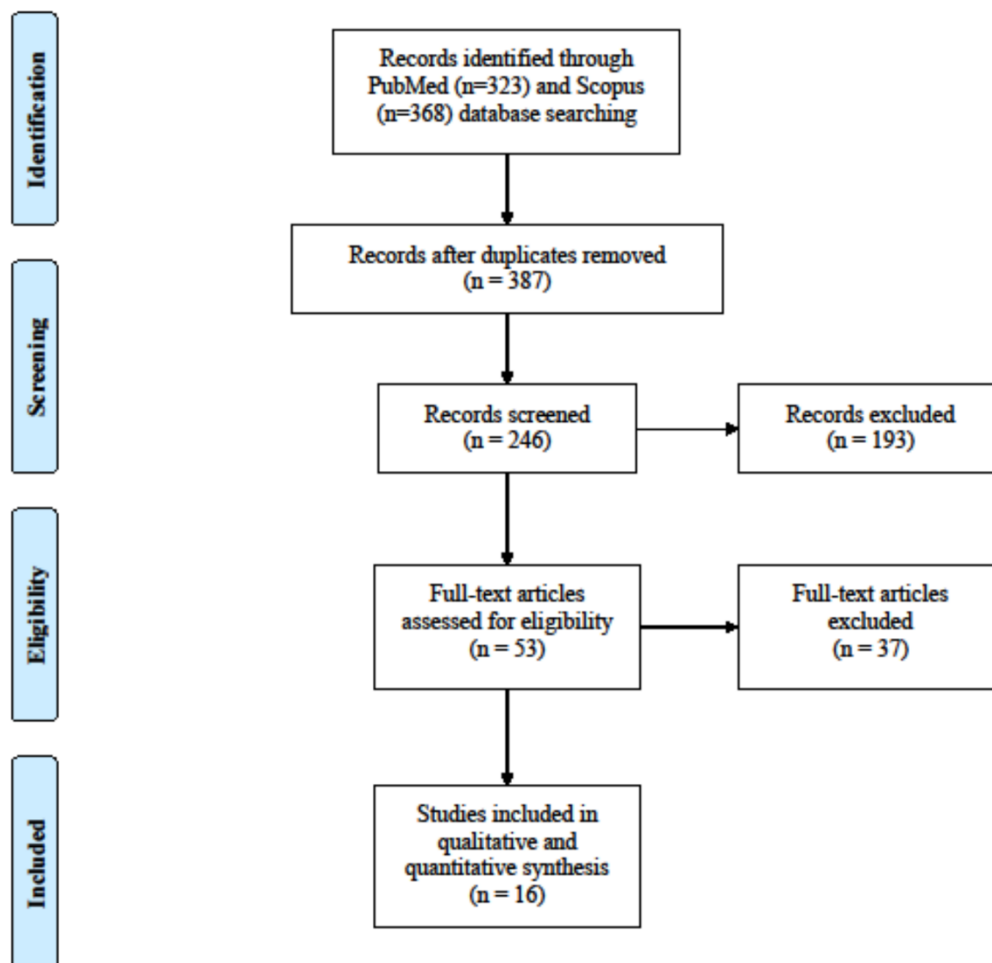
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Appendix A

Figure 1: Flow diagram of literature search and article selection process according to the PRISMA guidelines.



Appendix B

Table I: Summary of the main findings of the articles included in the study.

	Author, Year of Publication, Reference, and Article Type (n=patients)	Gender, Age Range	Clinical Presentation and History	Laboratory and Radiology Outcomes	Laparoscopy Outcomes
1	Liu et al. 2023 (67) Case report (n=1)	Male, 12 years	Pain and discomfort for three days. Intermittent of upper abdomen pain without nausea or vomit.	CT: fatty liver, omental infarction at the right of the transverse colon, fluid in the pelvis.	Clock wise rotation 540 degrees. Necrotic omentum. Eat liquid food 8 h after operation and discharge on second postoperative day.
2	Chen et al. 2022 (30) Case series (n=17)	Males (n=16) Female (n=1) 4-12 years	Right upper abdominal pain (n=5). Right middle pain (n=6). Right lower pain (n=5). Periumbilical pain (n=1). Pain duration: 1-6 days. Obesity (n=16). Four cases had fever and two had vomiting.	Leukocytosis (n=9). Elevated CRP (n=14). Ultrasound revealed inflammatory mass (n=5). CT showed mass in front of the right colon (n=10), near the ligamentum teres (n=2), Whirl sign (n=5), pelvic fluid (n=8). CT diagnosed POT (n=12). CT diagnosed appendicitis (n=5).	Pelvic sanguineous fluid (n=17). Hospitalization median time: 5 days. Relapse eight months postoperatively (n=1).
3	Elsayed et al. (21) 2021 Case series (n=3)	Males (n=2) female (n=1) 10-11 years	The first patient presented right abdominal and epigastric pain with rebound tenderness and standing straight difficulty. The second patient presented periumbilical pain shifted to right lower abdomen, rebound tenderness, vomiting. The third patient presented right lower abdominal pain, walking difficulty, tenderness, positive Rovsing sign and nausea. Normal weight (n=2), overweight (n=1).	Ultrasound with free fluid in the right lower abdomen (n=1). Ultrasound suggested appendicitis (n=2). Elevated WBC (n=3). Elevated CRP (n=3).	Hemorrhagic fluid in the pelvis (n=1). Omentum adherent to the right abdominal wall (n=1). Omentum adherent to the lower abdominal wall and sigmoid colon (n=1). Omentum adherent to the right abdominal wall below the liver margin (n=1). Hemorrhagic omental necrosis (n=3). Discharge on second postoperative day.
4	Elscherbeny et al. 2018 (9) Case series (n=2 with laparoscopy out of 4 patients)	Males (n=3) female (n=1) Age 9-14 years	Acute abdominal pain, nausea and vomiting (n=2), fever (n=2), right abdominal tenderness higher than the McBurney point. Obesity (n=2), recent trivial abdominal contact trauma history (n=1).	Leukocytosis. Normal ultrasound (n=3), suggesting appendicitis, eliciting tenderness by the probe (n=1).	Right hypochondrial omental location (n=2). Right hypochondrial and umbilical (n=1). Right lumbar location (n=1). Normal appendix (n=4). Discharge on the second postoperative day.
5	Madha et al. 2018 (7) Case report (n=1)	Male (n=1) 7 years	Right lower abdominal tenderness intensified after 24 hours. Duration two days. Exacerbated with oral intake, moving up from supine position, and ambulation. No fever or emesis. Abdominal distention. Pain progression and peritoneal irritation. Obese patient.	CT: Normal appendix and fluid in the pelvis. Leukocytosis with neutrophil shift.	Omental torsion with necrotic area adhered to cecum. Free blood in the pelvis. Infarcted omentum and appendix resection. Two more patients were treated without operation. Postoperative stay for one day.
6	Pogorelic et al. 2015 (22) Case report (n=2)	Males (n=2) 9 and 10 years	The first patient presented with sudden onset of right abdominal pain, low fever, nausea, two days before admission, direct and	Both patients had leukocytosis, and elevated CRP. Ultrasound was performed in the first patient and was	Torsion of greater omentum was found behind the liver, at the right upper abdomen. The affected part of omentum was twisted for 720 degrees in counterclockwise direction, and it

			rebound tenderness at the right iliac fossa. The second patient presented with pain of the right iliac fossa and vomiting, initiating one day before admission.	normal with small amount of fluid between intestinal loops at the right abdomen.	was edematous and necrotic. In the second patient, 520 degrees counterclockwise twisted omentum was located at the right ileocecal region, adhered to the lateral abdominal wall.
7	Werthheimer et al. 2014 (36) Case report (n=1)	Male 12 years	Gradually developed right abdominal pain in four days, worsened by movements and coughing, without nausea or vomiting, tenderness at the right abdominal quadrants and flanks. Overweight patient.	Normal WBC count and CRP. Ultrasound showed painful infiltration of the deep abdominal fat with a hyperechogenic image along its long axis, ovoid, homogeneous and located at the right flank between the abdominal wall and ascending colon. CT scan showed extensive heterogeneous infiltration of the deep abdominal fat in front of the right colon, extending from the hypochondrium to the iliac fossa. MRI showed a large area of heterogeneous infiltration in the deep abdominal fat in front of the ascending colon.	Large yellowish mass in the right flank with areas of loss of coloration, representing the pathological omentum and signs of venous distress with a combination of loss of color, a purplish appearance and venous congestion. Torsion around its vascular pedicle. Adhesion to the anterior abdominal wall. Small free serosanguinous peritoneal effusion.
8	Zanchi and Bellomo. 2012 (68) Case report (n=1)	Female 9 years	Obese patient. Two days pain history of the right iliac fossa mimicking appendicitis, sharp, constant, aggravated by movement, shifted to upper abdominal quadrant, tenderness and guarding.	Ultrasound showed minimal fluid amount in the Douglas cavity. Mild CRP elevation.	Necrotic omental mass at the right abdomen.
9	Lescher and Hebra. 2010 (49) Case report (n=1) Also reported a total case series (n=5, of whom 3 underwent laparoscopy)	Female 7 years In total: 4-12 years	Two days of pain history with voluntary and involuntary guarding in the epigastric region as well as left-sided tenderness with deep palpation, afebrile. Regarding the total patients, three presented right and two presented left lower abdominal pain. Four reported obese patients.	Leukocytosis. CT suspicious for omental torsion. In the total series, CT was diagnostic in four patients.	Omental torsion with a large area of omental infarct with resulting hemorrhage, normal appendix. Discharge on second postoperative day.
10	Nubi et al. 2009 (40) Case series (n=6 children out of 10 with primary omental infarction)	Males (n=4) females (n=2) 8-14 years	Right sided abdominal pain, in three patients as acute appendicitis, and in three patients recurrent moderate abdominal pain. Obesity history (n=5).	Ultrasound missed all six cases with laparoscopy, and diagnosed two cases who were treated conservatively, while CT was diagnostic in all cases.	Three patients underwent immediate laparoscopy, more three patients started conservative treatment but switched to laparoscopy after 3-5 days. Postoperative hospital stay after laparoscopy, 1-3 days.
11	Panagidis et al. 2008 (29) Case report (n=2)	Male (n=1) 8 years Female (n=1) 6 years	Right upper abdominal pain, slow onset for four days. No fever, nausea, vomiting, appetite loss, bowel habit changes. Progress to severe colicky pain with rebound tenderness. Moderately overweight. Right upper abdominal pain for six days. Nausea, vomiting, diarrhea. Low grade fever. Non-distended soft abdomen, rebound tenderness.	Abdominal x-ray: non-specific findings. CT: mesentery inflammation. Elevated WBC count and CRP. In both patients: Differential diagnosis of retrocecal subhepatic appendicitis.	Hemorrhagic omental mass attached to the ascending colon (patient 1) and the right lateral abdominal wall (patient 2), due to necrotic torsion of the right side of the omentum. Blood in the subhepatic space (patient 1). Serosanguineous fluid to the right paracolic gutter (patient 2). Postoperative stay for one day for both patients.
12	Costi et al. 2008 (51) Case series (n=1 child)	Male 16 years	Right lower abdominal pain. Positive rebound tenderness.	Normal WBC. Ultrasound showed thickened appendix and fluid.	Asymmetry of the greater omentum, which was hypoplastic on the left side and redundant on the right, presenting a segmental infarction secondary to torsion. Discharge on the first postoperative day.

13	Chan et al. (50) 2007 Case series (n=5)	Males, 5-11 years	Right lower abdominal pain (n=3). Epigastric pain (n=1). Periumbilical pain (n=1). Pain duration: 1-3 days. Absence of rebound tenderness or guarding. Obesity (n=5). All patients did not have nausea or vomiting, and all patients had a good appetite without rebound tenderness or guarding.	Leukocytosis (n=2). Ultrasound (n=3), and CT (n=1) did not diagnose POT. Free fluid (n=2) in ultrasound.	Gangrenous omentum (n=5). Rotated omentum adherent to anterior abdominal wall or ascending colon. All patients were discharged on the first postoperative day.
14	Mallik and Al-Bassam. 2006 (24) Case series (n=6)	Males (n=5) Female (n=1) 9-12years	Pain for 3-5 days. Nausea and vomiting only in 1 patient. Low grade fever in 1 patient. Right lower abdominal pain and guarding in all patients. Obesity history (n=6).	Ultrasound with unremarkable findings of air fluid level. Normal lab exams.	Serosanguinous fluid. Necrotic and infarcted omentum in all patients.
15	Valioulis et al. 2003 (28) Case report (n=2)	Male 13y Female 8y	First patient with pain of 3 days, low fever. Tenderness and guarding of right upper and lower abdomen. Second patient with right lower abdominal pain of 12 hours. Tenderness. Obesity (n=2).	First patient showed normal blood count and CRP. Moderate leukocytosis. Plain radiography with air fluid levels. Normal ultrasound Second patient with elevated WBC and neutrophils. Normal ultrasound.	Torsion of the right omental side with distal necrosis. Histopathology with diffuse interstitial hemorrhage and lymphocytic infiltration.
16	Gul et al. 2001 (26) Case series (n=1 child and 2 adults)	Male, 14 years	Obese patient, two days history of acute right iliac fossa pain, nausea, no anorexia or vomiting, positive tenderness, no guarding or rebound.	Normal laboratory outcomes.	Serous peritoneal fluid, distal right omental torsion and infarction, normal appendix. Discharge on second postoperative day.

Table II: Ultrasonography and CT examination outcomes compared.

	Study	Patients	Ultrasonography			CT		
			Performed	Diagnosed	Missed	Performed	Diagnosed	Missed
1	Liu et al. 2023 (67)	1	-	-	-	1	1	0
2	Chen et al. 2022 (30)	17	17	5	12	17	12	5
3	Elsayed et al. (21)	3	3	0	3	-	-	-
4	Elscherbeny et al. 2018 (9)	2	2	0	2			
5	Madha et al. 2018 (7)	1	-	-	-	1	0	1
6	Pogorelic et al. 2015 (22)	2	1	0	1	-	-	-
7	Werthheimer et al. 2014 (36)	1	1	0	1	1	1	0
8	Zanchi & Bellomo. 2012 (68)	1	1	0	1	-	-	-
9	Lescher and Hebra. 2010 (49)	5	-	-	-	5	4	1
10	Nubi et al. 2009 (40)	6	6	0	6	6	6	0
11	Panagidis et al. 2008 (29)	2	-	-	-	1	0	1
12	Costi et al. 2008 (51)	1	1	0	1	-	-	-
13	Chan et al. 2007 (50)	5	4	0	4	1	0	1
14	Mallik & Al-Bassam. 2006 (24)	6	6	0	6	-	-	-
15	Valioulis et al. 2003 (28)	2	2	0	2	-	-	-
16	Gul et al. 2001 (26)	1	-	-	-	-	-	-
	Total	56	44	5	39	33	24	9