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ORIGINAL ARTICLE

Lumbar level distribution of acute abdomen with no history of abdominal surgery or trauma: Is there an aggregation?*

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ABSTRACT

Objective: In the majority of the population, the anatomic location of intra-abdominal structures varies slightly but is at certain vertebral levels, excluding postoperative and traumatic positional changes. Our aim was to investigate the distribution of pathologic findings at each lumbar level in acute abdomen patients.

Materials and Methods: This retrospective study included patients admitted to the emergency department between May 2017 and 2019 without abdominal trauma or surgery. CT images by vertebral length were assessed by two radiologists. Primary and secondary findings for each condition were examined for each lumbar level.

Results: In 553/1008 patients (54.8%), CT had findings explaining the cause of pain. However, in 48/553 (8.67%), no primary or secondary findings were found in any lumbar level, and most (n=42) were gynecologic, while three had appendicitis and three had sigmoid diverticulitis. The distribution of primary and secondary findings is as follows: 19.16% (n=106) and 19.34% (n=107) for L1, 28.57% (n=158) and 21.33% (n=118) for L2, 16.09% (n=89) and 27.84% (n=154) for L3, 22.78% (n=126) and 27.48% (n=152) for L4, and 31.64% (n=175) and 18.26% (n=101) for L5, respectively. There were no patients with primary or secondary findings at any lumbar level, who did not also have findings at L1, L2, and L5. The CT assessment of L1, L2, and L5 yielded 91.32% (88.66-93.53%CI) sensitivity, 90.46% NPV (87.85-92.55%CI), and 95.24% (93.74-96.47%CI) accuracy.

Conclusion: Due to the specific anatomic location of the organs, acute abdomen findings in patients without trauma or surgical changes tend to cluster at certain lumbar levels.

Keywords: Acute Abdomen (D000006), Emergency Medicine (D004635), Lumbar Vertebrae (D008159), Tomography (D014057).

INTRODUCTION

Computed tomography (CT) has been widely accepted and indispensable for patients presenting with acute abdominal pain, supplanting traditional physical exams and history in many instances [1, 2]. The increased demand for CT assessment by emergency physicians seems understandable if one disregards the increase in both radiation exposure and workload in emergency radiology (ER) units [3-5].

In the majority of the population, the anatomical positions of the intra-abdominal structures vary slightly but are located at certain vertebral levels [6]. However, this verdict may not be appropriate for both posttraumatic and postoperative patients, as the distortion of the normal anatomic configuration may occur [7]. It should also be noted that certain pathological conditions (such as acute appendicitis, acute cholecystitis, urinary stones, diverticulitis) account for a large proportion of acute abdominal pain [8].

The axial CT findings of a particular population with acute abdomen who are admitted to the emergency department may accumulate in certain lumbar levels, over a wide period of a year.

With this study, we aimed to obtain two important results. First, to investigate the detection rate of major and minor findings at each lumbar vertebral level in a selected group of patients with acute abdominal pain. Second, to determine if there is a particular combination of spinal levels with optimal outcomes and the highest negative predictive value.

MATERIALS AND METHODS

Approval for this study was granted by the Institutional Ethics Board (GO 19/800). Informed consent was not obtained due to the retrospective nature of the study.

Data Collection

Between January 2017 and May 2019, patients who presented to the emergency department (ED) and underwent a whole abdominal CT (n: 3352) were documented. Subsequently, patients with posttraumatic injury (n: 1583) and a history of any abdominal surgery (n: 761) were excluded (Fig.1). A total of 1008 patients, as the final sample size, were enrolled in this study.

All documents (patient history, US findings, and other follow-up information besides final clinical admissions) of each patient including reports from CT were evaluated. Also, no follow-up patients with acute abdominal pain were included in the study to prevent sampling repetition.

CT Technique

All CT examinations included in the study were contrast-enhanced (iodinated water-soluble intravenous contrast medium -Iohexol 5mg/kg- was administered at a rate of 4ml/sn) and were performed in the emergency radiology station, via Somatom Perspective 64-slice Siemens® CT (Erlangen/Germany) device. Oral contrast agents were administered in 75.9% (n=766) of patients. The CT acquisition parameters were as follows: Tube voltage: 120 kV, tube current determined with optimized automatic exposure control (the ref mAs value of CT was 140 mAs), collimation thickness: 0.6-2 mm, tube rotation time: 0.6-1 seconds and collimated section thickness: 2-5 mm. Iterative reconstruction (ADMIRE, strength 2) with a 30s soft-tissue kernel was used as a reconstruction algorithm to reduce radiation dose.

CT Image Analysis

CT images limited to specific lumbar levels were assessed by two reviewers (E.A. and İ.İ.) prior to evaluation of the entire CT examination to avoid both bias and false positivity in the analysis of the images. İ.İ. and E.A. created the sample with the final diagnosis, and all patients in this sample were selected by consensus of them. The determination of the main pathological condition found in the patients was made by examining the entire clinical course and consultations of the patients. In addition, surgical reports, interventions and pathology reports, if any, were also reviewed.

All CT images were reevaluated by consensus of two radiologists with 5 years (A.G.E.) and 18 years (M.R.O.) of experience in abdominal radiology to define the lumbar level(s) in which primary and/or secondary findings were observed. The longitudinal

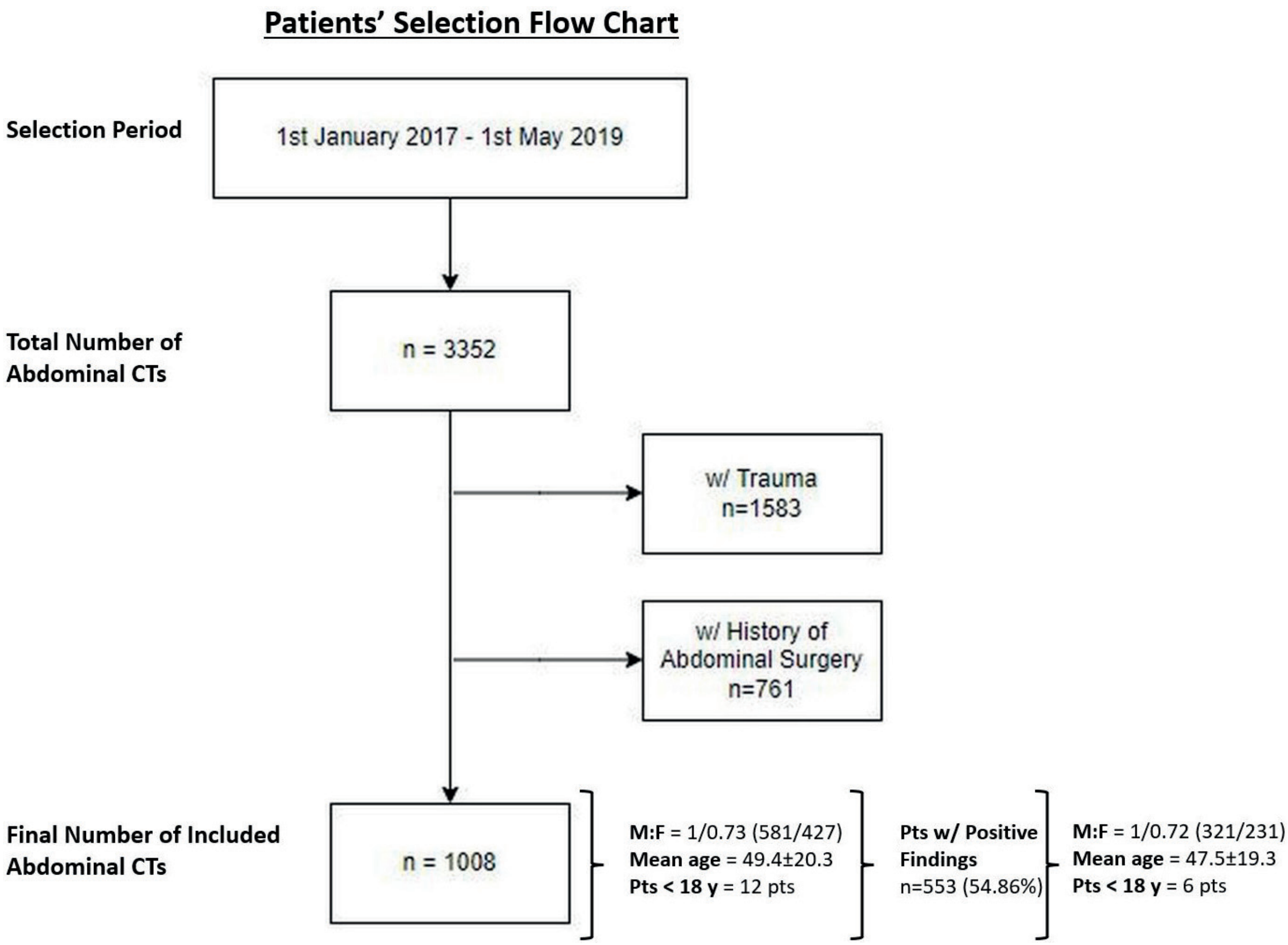

Figure 1. Flow Chart of Patients' Selection.

axis height of the assessment for each lumbar level was designated as shown in Fig. 2.

Fat stranding, pneumoperitoneum, fluid collection, urinary dilatation, biliary dilatation, and dilated bowel were considered as secondary findings in acute abdomen. Henceforth, a dilated appendix, a hydropic gallbladder with thickened wall, obstructive urinary stones, a perforation focus of the intestine, a tumor causing intestinal obstruction, etc., were considered as primary findings. The primary and secondary findings are listed in Table 1. In cases where the primary finding was accompanied by a secondary finding at the same vertebral level, the secondary finding was ignored and only the primary finding was recorded.

Considering the frequency of occurrence in the ED, patients who had findings explaining acute abdomen were divided into 10 groups and analyzed separately with respect to the distribution of primary and secondary findings for each lumbar level. These 10 groups consisted of appendicitis, hepatobiliary-pancreatic, inflammatory-infectious gastrointestinal (GI) diseases, diverticulitis - epiploic appendagitis, intestinal obstruction, gynecological, peritoneal - retroperitoneal and mesenteric diseases, urinary tract diseases, incidental malignancies, and miscellaneous causes.

Radiaiton Dose Calculation

Radiation exposure dose values for the CT examinations were recorded as CT Dose Index Volume (CTDIvol) and Dose Length Product (DLP) values within the PACS software (Syngo.Via, Siemens®). DLP values for each lumbar vertebra were calculated by determining the length of the vertebra in the z-axis direction using the topogram image (Fig.2). The DLP values of the segments with minor and major findings were summed and related to the total DLP values to determine the ratio of the actual radiation dose required and to decide which segments to scan to complete the examination.

Statistical Analysis

Data were summarized as "mean ± SD" or "median (with minimum-maximum)" for continuous variables, depending on the distributional

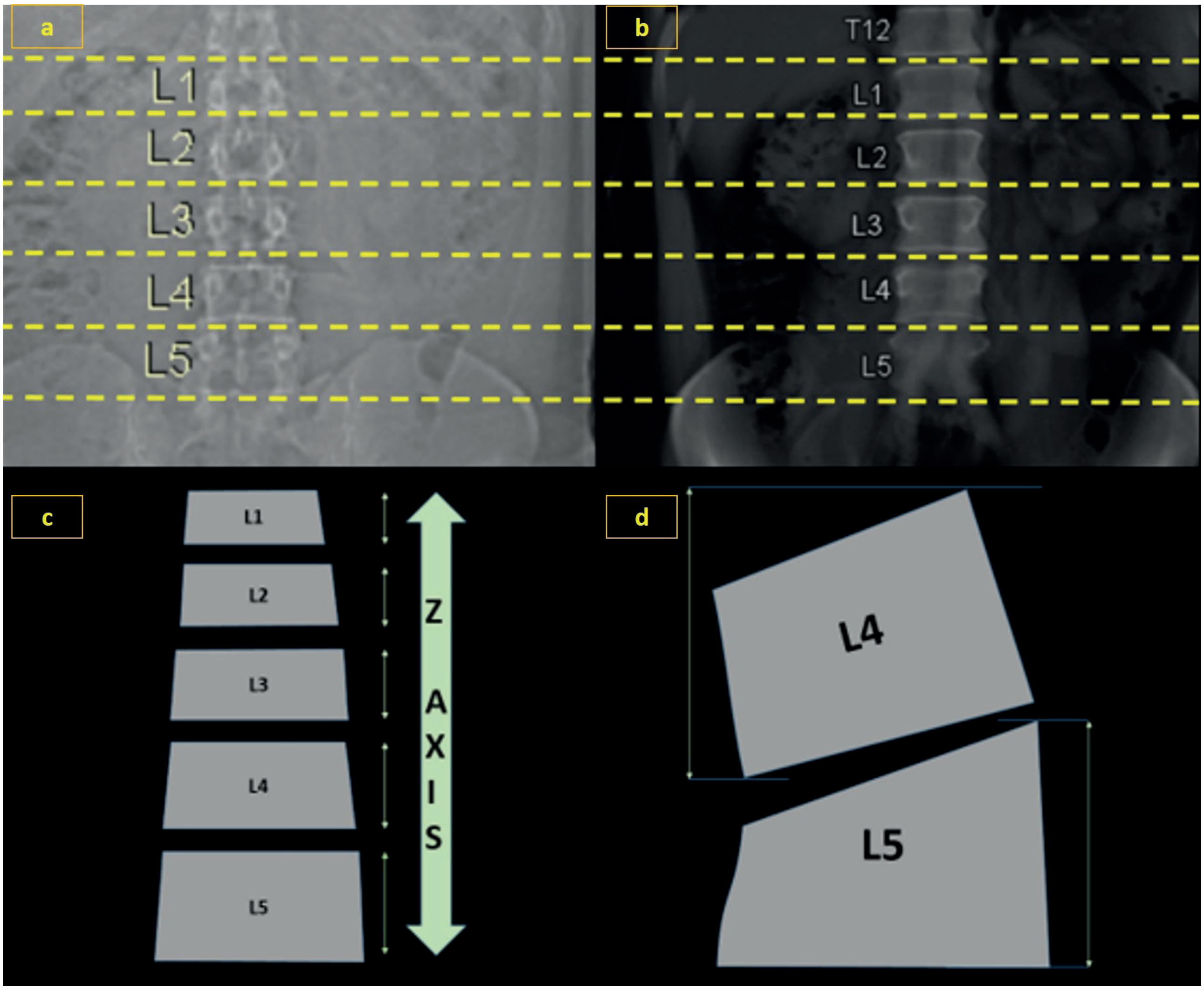

Figure 2. Determining the limits of scanning levels.

Topogram (a) and Maximal Intensity Projection (b) images alongside with simple illustrations used to determine the length of z-axis (c,d). Length for vertebrae were determined with topogram guidance (a), excluding intervertebral spaces (c). Though, in patients with abnormal vertebral order, the longer lateral margin of vertebral body were considered as the length of z axis, whether it overlaps which each other or not (d).

Table 1. The list of primary and secondary findings

Primary	Secondary
• Dilated appendix • Hydropic gall-bladder with thickened wall • Obstructive biliary or urinary stone • Biliary dilatation with thickened wall and fluid level • Pancreatic thickening with fat stranding, fluid collection or unenhancing area • Intestinal obstruction transition site • Perforation focus • Thickened intestinal wall • Inflammed diverticule or epiploic appendix • Ruptured or hemorrhagic cyst • Torsion site • Lymphadenopathy or tumor • Abscess or hematoma • Thrombosed vessel, dissection or ruptured aneurysm	• Mesenteric, omental, pelvic, retroperitoneal or perirenal fat stranding • Fluid collection • Peritoneal thickening§ • Pneumoperitoneum • Intestinal dilatatiom • Urinary dilatation • Biliary dilatation • Ill-defined visceral enhancement

§ Secondary peritonitis is considered as the secondary finding of the primary etiologies.

properties of the data. Normality of variables was tested using the Kolmogorov-Smirnov. Percentiles were given for categorical data. Kruskal-Wallis analysis was performed for comparison of DLP at different lumbar levels. For all tests, a two-tailed p-value of less than 0.05 was considered statistically significant.

RESULTS

Out of 1008 patients, the male/female ratio was 1/0.73 (581/427), while the mean age was 49.4 ± 20.3 (varied between 10-96), with 12 pediatric (<18) patients. Out of 1008 patients, CT assessments revealed normal findings in 455 patients (45.13%). In the remaining 553 patients (54.86%), CT assessments have positive findings for acute abdomen. Out of 553 patients, the male/female ratio was 1/0.72 (321/232), while the mean age was 47.5 ± 19.3 (varied between 14-95), with 6 pediatric (<18) patients.

The distribution of primary and secondary findings at each lumbar level, related to 10 different groups, is detailed in Table 2. In other respects, the distribution of sensitivity, negative predictive value (NPV), and accuracy for all combinations of multiple lumbar vertebrae are detailed in Table 3.

When the lumbar vertebrae alone were evaluated, most findings were noted at the L4 level (n:278). However, when all vertebral combinations were evaluated, the combinations containing L1, L2, and L5 together (n:505) were found to have the most findings among all combinations. See Table 4 for the distribution of findings detected for each pathologic condition at these 3 levels.

In 48 of 553 patients, no primary or secondary findings were noted in any of the lumbar levels. Most of them (n:42) were gynecological, while only 6 had appendicitis (n:3) and sigmoid diverticulitis (n:3). Because there were no false positives, positive predictive value (PPV) and specificity for all levels were estimated as 100%. The assessment of CT images at L1, L2, and L5 levels in 1008 patients yielded 91.32% (88.66-93.53% CI) sensitivity, 90.46% NPV (87.85-92.55% CI), and 95.24% (93.74-96.47% CI) accuracy in detecting the cause of acute abdominal pain.

Appendicitis, the most common cause of acute abdominal pain, was found in 95 patients (17.17%), while perforation was present in 13 patients. All patients with perforated appendicitis were also confirmed surgically. In three patients whose appendix was not perforated, no primary or secondary finding in any lumbar level was found as a reason for the pelvic localization.

Hepatobiliary and pancreatic causes of acute abdominal pain presented with imaging findings mostly at upper lumbar levels.

All patients with inflammatory or infectious GI tract conditions presented with primary or secondary findings at L1, L2, and L5 levels.

Of the 22 diverticulitis, 12 were sigmoid diverticulitis and 3 of them showed no primary or secondary findings at any lumbar level. Imaging findings in patients with intestinal obstruction were heterogeneously distributed among lumbar levels, however, %100 of patients in this group had primary or secondary findings at the L1, L2, and L5 levels.

Gynecologic emergencies were the group most commonly recognized at no lumbar level, with 42 (66.6%) of 63 patients. Of these 42 patients, most (n:39, 92.85%) had only secondary findings, while the remaining (n:3, 7.15%) had primary findings in the lumbar levels.

Condensed abdominal CT showed one of the highest performances in peritoneal-retroperitoneal, mesenteric, urinary conditions of non-traumatic abdominal emergencies as well as incidental malignancies and miscellaneous conditions presenting with acute abdominal pain since %100 of these patients in these groups presented with imaging findings at L1, L2 and L5 levels (Table 2 and 4).

The distribution of detected pathological conditions on CT and the number of primary and secondary findings on each vertebral level with the average lengths of these levels together with the DLP values are shown in Table 5.

The median DLP value obtained by scanning the entire abdomen was 404.17 mGy-cm, whereas the median DLP value obtained by scanning 5 lumbar levels was 102.81 mGy-cm. The median DLP value of L1,2,5 levels was found to be 60.68 mGy-cm, which is a significant dose reduction compared to scanning the whole abdomen (p<0.001).

Table 2. Distribution of primary and secondary findings

Pathological Conditions		L1	L2	L3	L4	L5
Appendicitis (n: 95)	Primary † Secondary ‡	0 (0%) 4 (4.21%)	1 (1.05%) 4 (4.21%)	1 (1.05%) 12 (12.63%)	22 (23.15%) 30 (31.57%)	81 (85.26%) 11 (11.57%)
Hepatobiliary and Pancreatic (n: 72) • Acute Cholecystitis (n: 42) • Acute Pancreatitis (n: 14) • Choledocholithiasis (n: 10) • Cholangitis (n: 6)	Primary Secondary	37 (51.38%) 25 (34.72%)	51 (70.83%) 16 (22.22%)	7 (9.72%) 24 (33.33%)	0 (0%) 4 (5.55%)	0 (0%) 1 (1.38%)
Inflammatory/Infectious GI Tract Conditions (n: 104) • Ileitis (n: 54) • Non-spesific Colitis (n: 24) • Jejunitis (n: 10) • Duodenitis (n: 6) • Enterocolitis (n: 4) • Pseudomembranous Enterocolitis (n: 3) • Typhilitis (n: 3)	Primary Secondary	9 (8.65%) 9 (8.65%)	19 (18.26%) 14 (13.46%)	23 (22.11%) 16 (15.38%)	40 (38.46%) 28 (26.92%)	15 (14.42%) 7 (6.73%)
Diverticulitis and Epiploic Appendagitis (n: 28) • Diverticulitis (n: 22) • Epiploic Appendagitis (n: 6)	Primary Secondary	0 (0%) 3 (10.71%)	3 (10.71%) 1 (3.57%)	0 (0%) 4 (14.28%)	4 (14.28%) 5 (17.85%)	15 (53.57%) 7 (25.00%)
Intestinal Obstruction (n: 61) • Ileal Obstruction (n: 27) • Jejunal Obstruction (n: 22) • Colonic (n: 14)	Primary Secondary	5 (8,19%) 31 (50.81%)	11 (18.03%) 45 (73.77%)	9 (14.75%) 48 (78.68%)	25 (40.98%) 28 (45.90%)	26 (42.62%) 25 (40.98%)
Gynecologic (n: 63) • Pelvic Inflammatory Disease (n: 33) • Adnexal Cyst Rupture (n: 26) • Adnexal Torsion (n: 3) • Pelvic Neoplastic Tumor (n: 1)	Primary Secondary	0 (0%) 0 (0%)	0 (0%) 3 (4.76%)	0 (0%) 4 (6.34%)	0 (0%) 9 (14.28%)	3 (4.76%) 18 (28.57%)
Peritoneal/Retroperitoneal, Mesenteric (n:39)** • Peritoneal Carcinomatosis (n: 12) • Sclerosing mesenteritis (n: 9) • Lymphoproliferative Disease (n: 7) • Mesenteric Lymphadenitis (n: 6) • Omental Infarct (n: 4) • Primary Peritonitis (n: 1)	Primary Secondary	20 (51.28%) 8 (20.51%)	29 (74.35%) 4 (10.25%)	23 (58.97%) 9 (23.07%)	24 (61.53%) 7 (17.94%)	21 (53.84%) 7 (17.94%)
Urinary Conditions (n: 37) • Urolithiasis (n: 19) • Pyelonephritis/Pyelitis (n: 16) • Bladder Cancer (n: 1) • Acute Tubulary Necrosis (n: 1)	Primary Secondary	10 (27.02%) 14 (37.83%)	20 (54.05%) 14 (37.83%)	8 (21.62%) 22 (59.45%)	3 (8.10%) 15 (40.54%)	4 (10.81%) 12 (32.43%)
Incidental Malignancies (n: 21) • Liver Metastasis (n: 8) • Colon Cancer (n: 7) • Pancreatic Cancer (n: 4) • Gastric Cancer (n: 2)	Primary Secondary	13 (61.90%) 4 (19.04%)	14 (66.66%) 3 (14.28%)	10 (47.61%) 4 (19.04%)	2 (9.52%) 8 (38.09%)	2 (9.52%) 5 (23.80%)
Miscellaneous (n: 33) • Vascular (n: 17) *** • Mesenteric Abscesses (n: 7) • Duodenal Perforation (n: 4) • Intramural Hematoma (n: 3) • Rectus Muscle Hematoma (n: 2)	Primary Secondary	12 (36.36%) 9 (27.27%)	10 (30.30%) 14 (42.42%)	8 (24.24%) 11 (33.33%)	6 (18.18%) 18 (54.54%)	8 (24.24%) 8 (24.24%)
General Distribution	Primary Secondary	106 (19.16%) 107 (19.34%)	158 (28.57%) 118 (21.38%)	89 (16.09%) 154 (27.84%)	126 (22.78%) 152 (27.48%)	175 (31.64%) 101 (18.26%)

† The number of the detection of primary findings for each vertebral level
‡The number of the detection of secondary findings for each vertebral level
* Indicates the percentage and number of patients with any primary and/or secondary findings at these levels among patients.
**Secondary peritonitis is considered as the secondary finding of the primary etiologies.
*** 5 were portal venous thrombosis, 4 were superior mesenteric arterial thrombosis, 3 were superior mesenteric venous thrombosis, 3 were non-occlusive mesenteric vascular occlusion, one of them was the rupture of abdominal aorta aneursym and one was the aortic dissection extending infrarenal level.

Table 3. Distribution of sensitivity, negative predictivity and accuracy for all combinations of multiple lumbar vertebrae

	Detected†	Missed‡	Sensitivity*	Negative Predictive Value*	Accuracy*
L1 – L2	n: 278	n: 275	50.27% (46.02 – 54.52%)	62.33% (60.34 – 64.28%)	72.72% (69.86 – 64.28%)
L1 – L3	n: 302	n: 251	54.61% (50.36 – 58.82%)	64.45% (62.33 – 66.51%)	75.10% (72.31 – 77.74%)
L1 – L4	n: 391	n: 162	70.71% (66.72 – 74.47%)	73.74% (71.61 – 76.17%)	83.93% (81.51 – 86.14%)
L1 – L5	n: 474	n: 79	85.71% (82.52 – 88.52%)	85.21% (82.44 – 87.60%)	92.16% (90.33 – 93.75%)
L2 – L3	n: 310	n: 243	56.06% (51.81 – 60.24%)	65.19% (63.02 – 67.29%)	75.89% (73.13 – 78.50%)
L2 – L4	n: 406	n: 147	73.42% (69.53 – 77.06%)	75.58% (72.94 – 78.05%)	85.42% (83.09 – 87.54%)
L2 – L5	n: 498	n: 55	90.05% (87.25 – 92.42%)	89.22% (86.55 – 91.40%)	94.54% (92.96 – 95.86%)
L3 – L4	n: 340	n: 213	61.48% (57.28 – 65.56%)	68.11% (65.78 – 70.36%)	78.87% (76.22 – 81.35%)
L3 – L5	n: 432	n: 121	78.12% (74.44 – 81.50%)	78.99% (76.26 – 81.49%)	88.00% (85.83 – 89.94%)
L4 – L5	n: 372	n: 181	67.27% (63.18 – 71.17%)	71.54% (69.05 – 73.91%)	82.04% (79.53 – 84.37%)
L1 – L2 – L3	n: 311	n: 242	56.24% (51.99 – 60.42%)	65.28% (63.11 – 67.39%)	75.99% (73.23 – 78.60%)
L1 – L2 – L4	n: 407	n: 146	73.60% (69.71 – 77.23%)	75.71% (73.06 – 78.17%)	85.52% (83.19 – 87.63%)
L1 – L2 – L5	**n: 505**	**n: 48**	**91.32% (88.66 – 93.53%)**	**90.46% (87.85 – 92.55%)**	**95.24% (93.74 – 96.47%)**
L1 – L3 – L4	n: 404	n: 149	73.06% (69.15 – 76.71%)	75.33% (72.69 – 77.79%)	85.22% (82.88 – 87.35%)
L1 – L3 – L5	n: 490	n: 63	88.61% (85.66 – 91.33%)	87.84% (85.13 – 90.11%)	93.75% (92.07 – 95.16%)
L1 – L4 – L5	n: 485	n: 68	87.70% (84.67 – 90.32%)	87.00% (84.27 – 89.32%)	93.25% (91.53 – 94.72%)
L2 – L3 – L4	n: 406	n: 147	73.42% (69.53 – 77.06%)	75.58% (72.94 – 78.05%)	85.42% (83.09 – 87.54%)
L2 – L3 – L5	n: 501	n: 52	90.60% (87.85 – 92.90%)	89.74% (87.11 – 91.89%)	94.84% (93.29 – 96.12%)
L2 – L4 – L5	n: 498	n: 55	90.05% (87.25 – 92.42%)	89.22% (86.55 – 91.40%)	94.54% (92.96 – 95.86%)
L3 – L4 – L5	n: 432	n: 121	78.12% (74.44 – 84.50%)	78.99% (76.26 – 81.49%)	88.00% (85.83 – 89.94%)
L1 – L2 – L3 – L4	n: 407	n: 146	73.60% (69.71 – 77.23%)	75.71% (73.06 – 78.17%)	85.52% (83.19 – 87.63%)
L1 – L2 – L3 – L5	**n: 505**	**n: 48**	**91.32% (88.66 – 93.53%)**	**90.46% (87.85 – 92.55%)**	**95.24% (93.74 – 96.47%)**
L1 – L2 – L4 – L5	**n: 505**	**n: 48**	**91.32% (88.66 – 93.53%)**	**90.46% (87.85 – 92.55%)**	**95.24% (93.74 – 96.47%)**
L1 – L3 – L4 – L5	n: 497	n: 56	89.87% (87.05 – 92.26%)	89.04% (86.37 – 91.24%)	94.44% (92.85 – 95.78%)
L2 – L3 – L4 – L5	n: 504	n: 49	91.14% (88.45 – 93.37%)	90.28% (87.67 – 92.38%)	95.14% (93.62 – 96.38%)
L1 – L2 – L3 – L4 – L5	**n: 505**	**n: 48**	**91.32% (88.66 – 93.53%)**	**90.46% (87.85 – 92.55%)**	**95.24% (93.74 – 96.47%)**

† Patients detected with primary or secondary findings
‡ Patients missed with any primary or secondary findings
* Values wthin parenthesis are 95% confidence interval.
Abbreviation: L1: 1st Lumbar vertebrae, L2: 2nd Lumbar vertebrae, L3: 3rd Lumbar vertebrae, L4: 4th Lumbar vertebrae, L5: 5th Lumbar vertebrae.

Table 4. Distribution of detection rate of pathological conditions on L1, L2 and L5

Pathological Conditions	Primary or Secondary Findings Detected†
Appendicitis (n: 95)	92 (96.84%)
Hepatobiliary and Pancreatic (n: 72) • Acute Cholecystitis (n: 42) • Acute Pancreatitis (n: 14) • Choledocholithiasis (n: 10) • Cholangitis (n: 6)	72 (100%)
Inflammatory/Infectious GI Tract Conditions (n: 104) • Ileitis (n: 54) • Non-spesific Colitis (n: 24) • Jejunitis (n: 10) • Duodenitis (n: 6) • Enterocolitis (n: 4) • Pseudomembranous Enterocolitis (n: 3) • Typhilitis (n: 3)	104 (100%)
Diverticulitis and Epiploic Appendagitis (n: 28) • Diverticulitis (n: 22) • Epiploic Appendagitis (n: 6)	25 (89.28%)
Intestinal Obstruction (n: 61) • Ileal Obstruction (n: 27) • Jejunal Obstruction (n: 22) • Colonic (n: 14)	61 (100%)
Gynecologic (n: 63) • Pelvic Inflammatory Disease (n: 33) • Adnexal Cyst Rupture (n: 26) • Adnexal Torsion (n: 3) • Pelvic Neoplastic Tumor (n: 1)	21 (33.33%)
Peritoneal/Retroperitoneal and Mesenteric (n: 39)** • Peritoneal Carcinomatosis (n: 12) • Sclerosing mesenteritis (n: 9) • Lymphoproliferative Disease (n: 7) • Mesenteric Lymphadenitis (n: 6) • Omental Infarct (n: 4) • Primary Peritonitis (n: 1)	39 (100%)
Urinary Conditions (n: 37) • Urolithiasis (n: 19) • Pyelonephritis/Pyelitis (n: 16) • Bladder Cancer (n: 1) • Acute Tubulary Necrosis (n: 1)	37 (100%)
Incidental Malignancies (n: 21) • Liver Metastasis (n: 8) • Colon Cancer (n: 7) • Pancreatic Cancer (n: 4) • Gastric Cancer (n: 2)	21 (100%)
Miscellaneous (n: 33) • Vascular (n: 17) *** • Mesenteric Abscesses (n: 7) • Duodenal Perforation (n: 4) • Intramural Hematoma (n: 3) • Rectus Muscle Hematoma (n: 2)	33 (100%)

† The number of the detection of primary or secondary findings for each vertebral level
**Secondary peritonitis is considered as the secondary finding of the primary etiologies.
*** 5 were portal venous thrombosis, 4 were superior mesenteric arterial thrombosis, 3 were superior mesenteric venous thrombosis, 3 were non-occlusive mesenteric vascular occlusion, one of them was the rupture of abdominal aorta aneursym and one was the aortic dissection extending infrarenal level.

Table 5. The number of primary and secondary findings at each vertebral level with the average lengths of these levels and DLP values

	L1 (2.27±0.25 cm)	L2 (2.41±0.26 cm)	L3 (2.5±0.25 cm)	L4 (2.64±0.27 cm)	L5 (2.73±0.32 cm)	L1,2,5 (7.41±0.71 cm)
Primary Finding	n = 106	n = 148	n = 89	n = 126	n = 243	n = 391
Secondary Finding	n = 107	n = 107	n = 154	n = 155	n = 103	n = 317
Primary and Secondary Finding	n = 213	n = 255	n = 243	n = 281	n = 346	n = 708
Median DLP Value† (mGy-cm)	18.67 (4.46-69.37)	19.60 (5.37-72.15)	20.33 (5.40-77.69)	21.44 (5.81-83.25)	22.45 (5.50-88.80)	60.68 (15.51-230.32)
Median CTDIvol: 8.17 mGy (2.35 – 27.75)						
Median DLP of Total Lumbar: 102.81 mGy-cm (26.79 – 391.27)						
Median DLP of Whole Abdomen: 404.17 mGy-cm (115.10 – 1490.81)						

† Values wthin parenthesis are minimum and maximum values, respectively.
Abbreviation: DLP: Dose-Length Product, CTDIvol: Computed Tomography Dose Index Volume, L1: 1st Lumbar vertebrae, L2: 2nd Lumbar vertebrae, L3: 3rd Lumbar vertebrae, L4: 4th Lumbar vertebrae, L5: 5th Lumbar vertebrae.

DISCUSSION

In this study, we found that the vast majority of primary, secondary, and total CT findings of common causes of acute abdominal pain were detected in specific lumbar levels. High sensitivity, NPV, and accuracy values were obtained when evaluation areas were restricted to certain vertebral levels.

Interrogation of specific pathologies belonging to the upper or lower abdominal region revealed that 96.1% of primary and 83.6% of total CT findings of pathological causes of the lower abdominal region including appendicitis, diverticulitis, and epiploic appendagitis were located together with gynecological diseases in L4 and L5 levels (Table 2). The 92.6% of primary and 78.1% of total CT findings of hepatobiliary and pancreatic causes that could be considered as a specific cause of acute upper abdominal pain were found in the L1 and L2 levels. These conditions, occurring mainly in the upper and lower regions of the abdomen, accounted for 54% of all included patients. Apart from the abovementioned causes of acute abdomen assigned to upper and lower abdominal pathologies, inflammatory and infectious GI tract diseases, intestinal obstruction, peritoneal/retroperitoneal and mesenteric diseases, urinary tract diseases, incidental malignancies, and miscellaneous conditions were also considered. These conditions can not be confined exclusively to the upper or lower abdominal region, as these diseases are common and it is difficult to localize them on the basis of physical examination findings. In 48 patients, no CT findings were noted in any of the lumbar levels. A significant proportion of these patients were gynecological. At this point, it should be noted that the diagnostic reliability of CT in gynecological patients is quite low compared to US and MRI. Therefore, the US may be performed first if the gynecologic disease is considered. Since the US is a crucial companion exam for both radiation dose saving and improved diagnostic performance to detect gynecologic emergencies [9-11].

It was observed that more findings were found in the lower lumbar regions such as L4 and L5. One of the reasons for this aspect is that the vast majority of acute abdominal causes originate from the lower regions [12-14]. In addition, the fact that these vertebrae are longer in the z-axis could also be a factor.

In our study, no finding was found in 455 patients to explain acute abdominal pain. The high percentage of unnecessary CT and hence unnecessary radiation exposure in the evaluation of acute abdomen may result from the clinician's tendency to avoid both medicolegal responsibility and clarification of the clinical situation. This study has important findings because it demonstrates the aggregation of lumbar level findings for the diagnosis of cause in certain patients with acute abdomen admitted to the emergency department over a 2-year period. In addition, one of the valuable findings of this study is that the primary and secondary findings for diagnosis are actually evaluated from a much shorter z- axis compared to the whole examination. Consequently, while this is not a perfect indicator of dose measurement, it is an indicator of how much less DLP value we can ideally use for diagnosis than is actually the case. Decent communication between the clinician and the radiologist plays a key role in determining the appropriate modality and avoiding radiation overexposure, as previous studies have shown [3,15,16]. Topographic classification of acute abdominal pain (pain in one of the four abdominal quadrants, diffuse abdominal pain, flank, or epigastric pain) contributes to the selection of the most appropriate imaging technique in the evaluation of acute abdominal pain [17]. Since appendicitis is one of the most common causes of acute abdomen, previous reports indicated that focused CT examination with scanning the lower abdomen only is efficient in assessment of acute appendicitis [18, 19]. In our study, which covers a broad concept of pathologic conditions, the area we evaluated in making the diagnosis on the z-axis actually appears to be a quite short segment in determining the cause of the acute abdomen. These points could be used in the future to develop focused CT protocols that cover the L1, L2, and L5 levels, or at least to complement artificial intelligence studies that consider these levels as "hotspots".

Our study has limitations. First, this was a retrospective study. Second, very few pediatric patients were included in this study because CT is rarely scanned for this group in our hospital, especially for non-traumatic patients. Third, because automatic exposure control was used in the CT studies, we were unable to obtain accurate DLP values for each lumbar level. The fourth limitation was the lack of comparison between the two reviewer's CT image assessments. Consensus reading and analysis are limitations of this study. Further studies may be needed for more robust conclusions, including multicenter studies with interobserver variability. The final limitation is that there were few patients for some of the miscellaneous pathologic conditions in this study, which spanned a 2-year period.

In conclusion, in patients without trauma or a history of abdominal surgery, acute abdominal causes tend to aggregate at certain lumbar levels. It should also be noted that when examining the abdomen CT, a radiologist should spend the most time to examine the L1, L2, and L5 levels, even if the examination includes the entire abdomen.

Author contribution

Study conception and design: AGE and MRO; data collection: AGE; analysis and interpretation of results: İSİ; draft manuscript preparation: AGE and EA. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

Approval for this study was granted by the Institutional Ethics Board (Hacettepe University, Medicine School - approval code: GO 19/800). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

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Conflict of interest

The authors declare that there is no conflict of interest.

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