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The Back Alleys and Dark Corners of Abdomen and Pelvis Computed Tomography: The Most Frequent Sites of Missed Findings in the Multiplanar Era

Mark A. Kliewer[1], Mikala R. Brinkman[2], J. Louis Hinshaw[3]

[1]Department of Radiology, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin, [2]Department of Radiology, Central Illinois Radiological Associates, Peoria, Illinois, [3]Department of Radiology and Urology, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin, United States.

***Corresponding author:**
Mark A. Kliewer,
Department of Radiology,
University of Wisconsin
School of Medicine and Public
Health, Madison, Wisconsin,
United States.

mkliewer@uwhealth.org

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ABSTRACT

Objectives: Radiologists reading multiplanar abdominal/pelvic computed tomography (CT) are vulnerable to oversight of specific anatomic areas, leading to perceptual errors (misses). The aims of this study are to identify common sites of major perceptual error at our institution and then to put these in context with earlier studies to produce a comprehensive overview.

Material and Methods: We reviewed our quality assurance database over an 8-year period for cases of major perceptual error on CT examinations of the abdomen and pelvis. A major perceptual error was defined as a missed finding that had altered management in a way potentially detrimental to the patient. Record was made of patient age, gender, study indication, study priority (stat/routine), and use of IV and/or oral contrast. Anatomic locations were subdivided as lung bases, liver, pancreas, kidneys, spleen, mesentery, peritoneum, retroperitoneum, small bowel, colon, appendix, vasculature, body wall, and bones.

Results: A total of 216 missed findings were identified in 201 patients. The most common indication for the study was cancer follow-up (71%) followed by infection (11%) and abdominal pain (6%). The most common anatomic regions of error were the liver (15%), peritoneum (10%), body wall (9%), retroperitoneum (8%), and mesentery (6%). Data from other studies were reorganized into congruent categories for comparison.

Conclusion: This study demonstrates that the most common sites of significant missed findings on multiplanar abdominal/pelvic CT included the mesentery, peritoneum, body wall, bowel, vasculature, and the liver in the arterial phase. Data from other similar studies were reorganized into congruent categories to provide a comprehensive overview.

Keywords: Abdominal computed tomography, Perceptual error, Overview

INTRODUCTION

In negotiating the complex internal landscape of the abdomen and pelvis, radiologists reading multiplanar computed tomography (CT) image stacks are vulnerable to systematic oversight of some anatomic areas, leading to a higher frequency of false-negative perceptual errors (misses) in these areas. Some of these misses seem to occur repeatedly at certain sites. These sites may be outside the typical search pattern, complex anatomic passages difficult to parse, or simply areas that tend not to be examined with a sufficient level of care.[1-14]

Studies of search patterns for abdominal/pelvic CT (henceforth, "abdominal CT") have revealed substantial variability among readers with regard to thoroughness, sites of fixation, and technique.[15-17] Further, radiologists are notoriously bad at knowing where they have looked on an image.[18,19] Therefore, the recognition of blind spots might suggest how search strategies might be optimized and ultimately codified in a way that could be taught to novice readers.

The few previous studies of misses on abdominal CT have provided data from single institutions, but none has collated and reclassified error into congruent categories so to provide a more comprehensive overview in the multiplanar era.[12-14] Indeed, many of these studies were performed before multiplanar reformation displays had become widely in use. Such an overview is more likely to be generalizable and relevant to the broader radiology community.

Identifying the sites where perceptual misses occur most frequently is one way to deduce the location of blind spots. The goals of this study are to identify and catalogue common sites of perceptual error at our institution and to put these in context with earlier studies.

MATERIAL AND METHODS

This study was conducted under the auspices of the quality assurance program at our institution. We retrospectively reviewed the quality assurance database over an 8-year period for cases where a major perceptual error was noted on CT examinations of the abdomen and pelvis. All of the studies in the database had been interpreted at a single institution, which is a large academic regional medical center that draws cases from an inpatient hospital, several community clinics, an emergency room with a level 1 trauma center, and a comprehensive cancer center. All cases had been interpreted by subspecialty trained abdominal radiologists.

A major perceptual error was defined as a missed finding that had altered management in a way potentially detrimental to the patient. Determination of clinical significance was made by the study authors after review of the electronic medical record, correlation with available pathology or surgical findings, and discussion with the referring clinician if needed.

Errors had been discovered either on later examinations, during review with clinical teams or tumor boards. All such errors had been recorded in a central quality assurance database and discussed at quarterly abdominal imaging conferences.

Those abdominal CT studies identified as containing error were reviewed, and record was made of patient age, gender, study indication, study priority (stat/routine), and use of IV and/or oral contrast. Additional information included the nature of the finding (metastasis, infection, trauma, etc.); the anatomic region involved; the technical quality of the study; the clinical significance of the error; the day of the week; and any confirmatory studies or pathology.

Indications were grouped into the following categories: Abdominal pain, infection, cancer, aneurysm, trauma, pre-operative evaluation, post-operative evaluation, flank pain/hematuria, and shortness of breath. Where studies might fall into more than one category, the primary indication listed on the requisition was used.

Anatomic locations were defined as mesentery/peritoneum, small bowel, vasculature, hepatobiliary, colon, retroperitoneum, pelvis, body wall, appendix, bones, mediastinum, renal, lung, pancreas, collecting system, and spleen. The age of patients was grouped by decade.

All statistical comparisons were made using z-tests for a single sample proportion. A nominal two-sided p-value of less than 0.05 was regarded as statistically significant.

RESULTS

A total of 216 false-negative errors (misses) on 201 patients from the database were determined to be clinically significant. More than 1 error on the study or the same error made on multiple studies was found for 22 of the 201 patients (10%).

Patient age ranged from 18 to 93 years, with the most common decade of age being 60–69 years (n = 56, 26%). There 123 errors (57%) made in male patients as compared to 93 (43%) in female (P = 0.04).

All errors had been reviewed and verified by consensus at the quarterly QA conference [Figures 1-6]. Surgical findings or biopsies were available to confirm the error for 61 cases (28%). IV contrast was used in 194/216 studies (90%) and both IV and oral contrast were used in 155/216 studies (72%). Only two studies were considered technically poor (1%): One due to motion and one due to delayed passage of oral contrast. Almost all of the cases were ordered as routine studies (n = 207, 96%) with a few stat studies (n = 9, 4%).

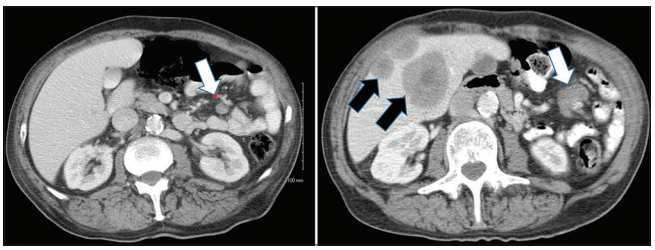

Figure 1: A 48-year-old female with ovarian cancer and rising CA-125. A 1.1 cm mesenteric nodule (white arrow) was missed on the initial scan (a), but discovered 7 months later after enlargement (white arrow) and the development of liver metastases (black arrows) (b).

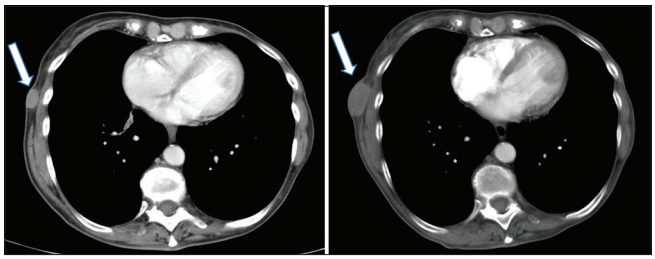

Figure 2: A 71-year-old female with breast cancer. A 2 cm right lateral chest wall lesion (arrows) was missed on the initial scan (a), but identified 2 months later when larger (b).

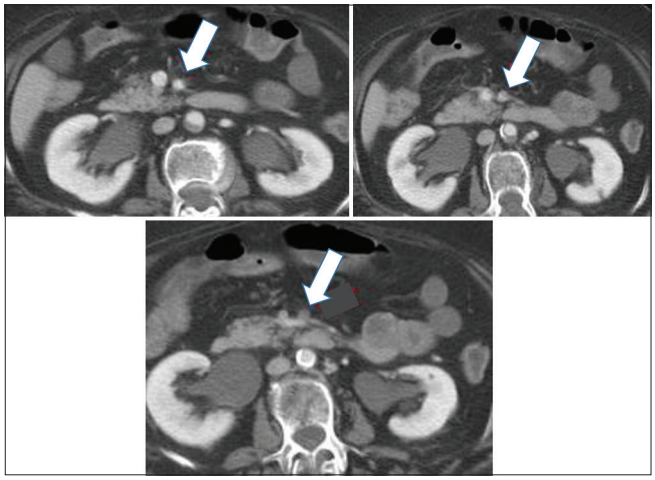

Figure 3: A 74-year-old female presented with nausea, vomiting, and atrial fibrillation. Three slices from the scan are displayed from superior to inferior (a-c). On review of the scan, occlusion of the superior mesenteric artery was not initially identified (arrows). The patient underwent exploratory laparotomy and was found to have ischemic small bowel. The patient died soon thereafter.

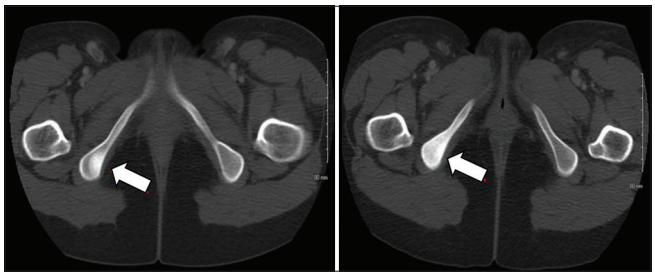

Figure 4: A 19-year-old woman with endometrioid uterine cancer. Sclerotic bone metastasis in the right ischium (arrow) was not on the initial study (a), but continued to grow and was identified on follow-up study approximately 3 months later (b).

There were fewer errors on the weekend (n = 15, 7%) than during the week (n = 211, 93%) ($P < 0.0001$), likely related to changes in study volume.

The indication most commonly associated with error was cancer follow-up (n = 153, 71%), followed by infection (n = 24, 11%), abdominal pain (n = 22, 6%), flank pain

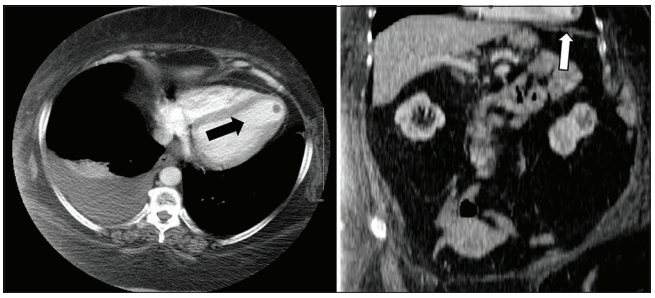

Figure 5: A 66-year-old female undergoing CT for follow-up evaluation for renal mass. The left ventricular aneurysm containing thrombus was not seen on either the axial (a) (black arrow) or the coronal view (b) (white arrow).

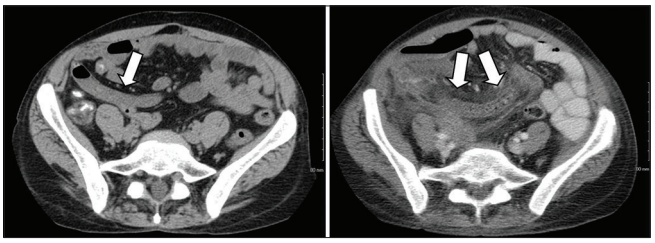

Figure 6: A 50-year-old female with nonspecific abdominal pain. On initial CT study, the dilated appendix was misinterpreted as a small bowel loop (arrow). The patient developed peritoneal signs prompting a follow-up CT 2 days later; the abnormal appendix was misinterpreted as an inflamed small bowel loop (arrows). The patient's condition worsened and she was taken to surgery where gangrenous appendicitis with perforation was found.

(n = 11, 5%), trauma (n = 4, 2%), aneurysm follow-up (n = 4, 2%), and post-operative follow-up (n = 4, 2%). The missed finding was related to the indication for the study 71% of the time (n = 153). The most common indication was neoplasm follow-up (n = 151, 70%).

The most common anatomic regions of error were the liver (n = 33, 15%), peritoneum (n = 21, 10%), body wall (n = 20, 9%), retroperitoneum (n = 18, 8%), and mesentery (n = 14, 6%). The frequencies of error by sites or anatomic region are listed in Table 1.

Of the 33 misses within the liver, 48% (16/33) were metastases from 1 to 2 cm diameter, and 11 of these 16 (69%) were hypervascular. There were two missed liver serosal metastases. There were seven misses that involved the hepatic vessels and five of these involved the portal vein (gas, thrombus, and vascular fistula). There were three misses within the bile ducts (two stones and one mass).

Of the 20 errors in the body wall, 16 (80%) were missed soft tissue nodules, and of these, 10 (10/16, 63%) were intramuscular metastases. Four (20%) were small abscesses. Misses in the colon included 4 masses (4/12, 33%), 2 fistulas (2/12, 17%), 1 case of diverticulitis (1/12, 8%), and 1 perforation (1/12, 8%).

Table 1: False-negative perceptual errors (misses) grouped by anatomic location.

Anatomic region	*n*	Percentage of total
Liver	33	15
Peritoneum	21	10
Body wall	20	9
Retroperitoneum	18	8
Mesentery	14	6
Lung bases (including heart)	13	6
Colon	12	6
Pelvic mass	10	5
Bones	8	4
Pancreas	8	4
Hepatic vessels	7	3
Kidney	7	3
Small bowel	6	3
Spleen	6	3
Ureter	5	2
Mesenteric vessels/celiac axis	5	2
Pelvic lymph nodes	4	2
Aorta	4	2
Renal pelvis	3	1
Appendix	3	1
Urinary bladder	3	1
Bile ducts	3	1
Pulmonary emboli	2	1
Gallbladder	1	<1
Total	216	100

Of the 21 errors in the peritoneum, 7 (33%) involved soft-tissue nodules of 1–3 cm diameter. Of the 14 errors in the mesentery, 7 (50%) involved soft-tissue nodules of 1–3 cm diameter, 7 (50%) were adjacent to or intermingled with bowel, 3 (21%) were in the left upper quadrant, 2 (14%) were at a bowel resection site, and 2 (10%) were interloop abscesses.

For the retroperitoneum, the most common error was missed nodules or lymph nodes (9/18, 50%). There were three missed adrenal masses (3/18, 17%). The gastrohepatic ligament was the site of three misses. Of the 15 misses at the lung bases, 11 (73%) were pulmonary nodules, 2 (13%) were pulmonary emboli, 1 (7%) was a left ventricular aneurysm [Figure 5], and 1 (7%) a metastasis in the right atrium.

DISCUSSION

Our study demonstrates that the most common sites of perceptual error (misses) on multiplanar abdominal/pelvic CT involved the liver, peritoneum, body wall, and retroperitoneum [Figures 1 and 2]. These four sites constituted fully 42% of all errors [Table 1]. The remainder of sites offers intriguing glimpses into where search patterns may contain deficits for many readers.

The small size (1–2 cm) of many of the missed lesions was likely a factor in large organs like the liver. The relatively high percentage (69%) of hypervascular lesions missed in the liver suggests that increased scrutiny of arterial phase sequences might be warranted. The number of misses in the body wall musculature, the gastrohepatic ligament, and the peritoneum also indicate areas that merit greater attention. Finally, the mesentery, colon, and abdominal/pulmonary vessels (considered collectively) were sites of a sizable number of cases (18%) [Figures 3 and 5].

As a rule, blind spots tend to be where disease prevalence is relatively low, the anatomy is complex and changeable (e.g., the bowel), or the lesion lacks depth in the plane of study (polar renal lesions and gastric lesions on axial images). Low prevalence of disease is well known to lead to decreased scrutiny; this is a phenomenon well documented in the visual science literature and termed "the prevalence effect."[20]

Our tally of misses by location is largely concordant with those of the five earlier studies that provide tallies [Table 2]. To be sure, these earlier studies vary with regard to a variety of factors (patient population, type of practice, study focus, criteria, grouping, and categories), but general trends can be compared. Those studies found that the most frequent misses on the abdominal CT are in the vascular system (blood clots), the bowel, the musculoskeletal system, and the body wall.[1-3,5-7,9] Of misses in the vascular system, pulmonary emboli figured prominently.[1,6,9] Misses falling into the second tier of frequency included those in the ureters, mesentery/omentum, and some useful perspective articles propose certain areas to be particularly perilous blind spots: The pulmonary arteries, stomach, bowel, body wall, and pelvic/paraspinal muscles.[6,7]

The mesentery/peritoneum, body wall, and vasculature were common locations of misses in our study [Table 1]. Before structured reporting, these sites were often not explicitly mentioned in reports, which may have caused them to be forgotten and uninspected; this is to invert the aphorism to out of mind, out of sight. If true, structured reporting might serve to mitigate errors by directing attention to areas that might be otherwise neglected.

Missed metastasis was most common miss in our and other studies [Figures 1,2,4]. The most frequent areas for missed metastasis were the gastrointestinal tract, the peritoneum, the neural axis, and the musculoskeletal system.[1-3] Feasibly, abdominal radiologists might miss findings in such areas as the musculoskeletal system or the neural axis due to lack of specific expertise. Likewise, the number of missed cancers in the colon only confirms what all abdominal radiologists know: The unprepped colon is five feet of hazardous road.[4]

The location of blind spots has been a perennial topic of talks and exhibits at major meetings. We searched 7 years

Table 2: Studies reporting misses by anatomic area for abdominal/pelvic CT. Studies vary with regard to a variety of factors (method of discovery, error significance, patient population, type of practice, study focus, criteria, grouping, and categories), but general trends and commonalities are evident. Data in all studies were reorganized so to conform to congruent anatomic categories. Value indicated the significance of the errors. The mesentery category includes the omentum.

Study	Number misses	Value	Reader level	Solid organs (%)	Liver (%)	Pancreas (%)	Kidney (%)	Spleen (%)	All bowel (%)	Colon (%)	Small bowel (%)	Peritoneum (%)	Body wall (%)	Mesentery (%)	Lung bases (%)	Musculoskeletal (%)	Blood vessels (%)
Current study	216	High	Faculty	25	15	4	3	3	9	6	3	10	9	6	6	4	6
Wildman-Tobriner *et al.*[1]	145	High	Resident	28					32							5	19
McCreadie *et al.*[10]	41	High	Both			15			22					12		32	32
Rosenkrantz and Bansal[5]	660	All levels	Faculty	20	7	3	8	2	11	5	6		10	6	6	10	12
Chin *et al.*[9]	184	All levels	Both	32	10	9	13	1	17	12	5	3	1			9	13
Donald and Barnard[2]	167	All levels	Both	13	5	4	4		8	6		2				10	14

(2012–2019) of RSNA abstracts for the words "forgotten," "neglected," and "overlooked" and found entries making the claim of neglect for the omentum, diaphragm, umbilicus, vagina, vaginal fornices, fallopian tubes, prostate, stomach, duodenum, ligament of Treitz, jejunum, cecum, colon, rectum, anus, pelvic floor, perineum, SMA, IMA, celiac axis, hepatic artery, ureters, urinary bladder, heart, sternum, retrocrural space, breasts, pulmonary arteries, spleen, spine, lymph nodes, and body wall. These claims, though unsubstantiated, do call attention to even more specific sites where subtle findings might lurk.

One limitation of this study is the likelihood of incomplete capture of cases containing error. It is virtually impossible to insure that all cases containing error would be discovered and reported. The validity of the tally, though, would tend to be supported by the size of the series, the long period over which the cases were gathered, and the broad concordance with earlier studies.

CONCLUSION

In summary, this study identifies common sites of misses made on multiplanar abdominal CT studies at a single institution and compares these across previous studies. Modifications to a standard search pattern might allocate extra attention to such areas as vasculature, mesentery, bowel, body wall musculature, and the liver in the arterial phase, especially when these sites are particularly pertinent to study indication. Further, structured reports might be constructed such that the act of reporting draws attention to particular sites that tend to be overlooked. And finally, the recognition of common error might guide how search patterns could be optimized, modified, and taught to trainees.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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