The fallacy of a roadmap computed tomography after an abdominal gunshot wound: A road that leads to nowhere

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BACKGROUND: The 2019 Western Trauma Association guidelines recommend an abdominopelvic computed tomography (CTAP) in patients with a question of abdominal penetration after a gunshot wound. However, it is common practice to obtain a CTAP to provide a roadmap for an operation or to potentially alter management even in patients with classic indications for a laparotomy. The hypothesis for this study was that a CTAP for preoperative planning has no value in patients with an abdominal gunshot wound.

METHODS: This was a retrospective study from 2017 to 2022 of patients with an abdominal gunshot wound who had a preoperative CTAP. Data collection included clinical characteristics and CTAP and operative findings. Admission hypotension, abdominal pain and/or peritonitis, evisceration, and a transabdominal trajectory were considered clear indications for laparotomy. Computed tomography and operative findings were compared to determine concordance and if computed tomography altered management.

RESULTS: There were 149 patients included in the study, of which 72.5% had a clear indication for laparotomy. The CTAP findings were concordant with operative findings in 57.0% of patients, while additional injuries were found at laparotomy in 36.2% of patients. Based on CTAP, a negative diagnostic angiogram was performed in three patients (2.0%). Three patients (2.0%) underwent a trial of nonoperative management based on CTAP findings. All underwent laparotomy after a clinical change. Six patients (4.0%) had a nontherapeutic operation; all patients had findings suspicious for either a hollow viscous injury or a vascular injury on preoperative imaging.

CONCLUSION: While a CTAP scan may help to define an intra-abdominal trajectory when the trajectory is unclear, it does not alter management in those with indications for operation. In addition, CTAP missed injuries in a third of patients and contributed to all six nontherapeutic laparotomies. A preoperative CTAP has minimal value in patients who have indications for an operation. (*J Trauma Acute Care Surg.* 2024;97: 785–790. Copyright © 2024 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Diagnostic Test/Criteria; Level IV.

KEY WORDS: Abdominal gunshot wound; computed tomography; gunshot wound; penetrating trauma.

Historically, the evaluation and management of the trauma patient relied heavily on the physical examination and the clinical condition of the patient. For abdominal gunshot wounds specifically, patients underwent a laparotomy if they had hemodynamic instability, evisceration, and peritonitis.[1–4] However, advancements in technology have significantly transformed the landscape of how trauma patients are assessed, triaged, and managed.

Computed tomography has served as an important adjunct in the assessment of trauma patients and may alter care.[5] The 2019 guidelines from the Western Trauma Association recommend an abdominopelvic computed tomography (CTAP) in patients with a question of abdominal penetration after an abdominal gunshot wound (AGSW).[6] A CTAP theoretically may alter how an injury is addressed, either with operative management, with an endovascular approach, or with observation. Some surgeons may argue that a CTAP provides a "roadmap" to guide an operation. While there are no data to quantitate how often surgeons are obtaining a CTAP to serve as a "roadmap," it anecdotally appears to occur rather frequently in trauma centers across the nation. Further, data regarding the utility of CTAP in patients that require an operation are lacking.

The aim of this study was to characterize the role of a preoperative CTAP in patients presenting with an AGSW. We hypothesized that preoperative CTAP would correlate poorly with intraoperative findings in patients with an AGSW who present with classic indications for laparotomy and does not alter management.

PATIENTS AND METHODS

Study Design, Data Collection, and Categorization

A retrospective review was conducted of trauma patients presenting after an AGSW who required a laparotomy at a high-volume, academic, urban Level 1 trauma center from January 2017 to September 2022. Patients who had a preoperative CTAP were selected for further analysis, while those with sealed records were excluded.

Data collection included age, sex, race, bullet trajectories, presence of abdominal pain, and/or peritonitis on initial physical

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examination, CTAP and operative findings, concordance between CTAP and operative findings, injury severity, and mortality. Information regarding trajectories was either gathered from documentation or determined by putting together descriptions of the location of the gunshot wounds and any bullet fragments. A consensus was reached for each patient by two of the authors for each patient (M.V. and N.K.D.). The documented history and physical note were used to determine if abdominal pain and/or peritonitis was present. In addition, the CTAP report was reviewed to collect injuries identified on imaging. Operative reports were reviewed to determine both injuries identified and interventions delivered at the time of laparotomy. Details regarding endovascular procedures were also collected.

A patient was considered to have a clear indication for laparotomy based on the presence of any of the following: hypotension on admission (as defined as systolic blood pressure of <90 mm Hg), presence of abdominal pain and/or peritonitis, and/or evisceration. If all injuries on CTAP corresponded to all injuries identified at laparotomy, then the CTAP was considered concordant. Abdominopelvic computed tomography was considered to be concordant if a questionable injury correlated with an intraoperative finding. For example, if CTAP demonstrated the presence of pneumoperitoneum or free fluid and a small bowel injury was identified intraoperatively, the CTAP was considered to be concordant with the operative findings.

Clinical Practice and Setting

Abdominopelvic computed tomographies were ordered at the discretion of the attending trauma surgeon. A patient may have undergone imaging if the trajectory was not clear, if there were multiple trajectories involved, or to characterize additional injuries outside of the abdominal cavity. Patients were transported to the computed tomography scanner, which was housed within the trauma resuscitation bay. Computed tomography scans were conducted with a 64-slice scanner or 256-slice dual-energy scanner. In addition to intravenous contrast, a patient may have been given rectal contrast if there was a need to specifically evaluate for a colorectal injury. Imaging was interpreted by an in-house attending trauma radiologist who was physically present and available to discuss imaging findings 24 hours a day with the trauma team. An attending surgeon may have elected to perform a diagnostic laparoscopy prior to proceeding to a laparotomy.

Statistical Analysis and IRB Approval

The primary outcome was the rate of concordance between CTAP and intraoperative findings. Data are summarized as percentages for categorical variables, while continuous variables were summarized with means with SDs and medians with interquartile ranges. Categorical variables were compared with a Fisher's exact test or χ^2 test, where appropriate. All statistical analyses were performed using IBM SPSS for Macintosh, version 28 (IBM Corp., Armonk, NY). This study was approved by the governing institutional review board. The requirement for informed consent was formally waived. The Strengthening the Reporting of OBservational studies in Epidemiology guideline was used for this study (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/D874).

RESULTS

There were 149 patients who met the inclusion criteria over the six-year study period. The median age was 27 years and 91.9% were male (Table 1). The majority (87.9%) of patients were Black. A substantial proportion was normotensive at the time of admission. Over half (58.4%) had abdominal pain at the time of evaluation with 8.1% having peritonitis. No patients presented with evisceration. Over half (51.0%) of the study population had multiple trajectories, while 19.5% had a clear transabdominal trajectory. The median abdomen/pelvis Abbreviated Injury Scale score and Injury Severity Score were 3 and 19, respectively. No patients in this series underwent a diagnostic laparoscopy prior to laparotomy. Two patients (1.3%) expired in the hospital.

Most patients (72.5%) had a clear indication for laparotomy based on findings at the time of initial assessment. The colon or rectum (42.3%) were most commonly either clearly injured or suspected to have been injured on imaging, followed by liver (33.6%) and kidney (22.1%). A hollow viscus injury was suspected in 67.8% of patients; this was more likely to be suspected or identified in patients with a clear indication for laparotomy compared with those who did not (73.1% vs. 53.7%, $p = 0.04$). No patients in this series had a suspected ureteral injury on preoperative imaging.

The colon and/or rectum (50.3%) was mostly commonly found to be injured at the time of laparotomy followed by small bowel (39.6%) and liver (30.2%). While 45 patients had a liver injury, 12 of these patients did not require an intervention to address the liver injury. Two patients (1.9%) had an injury to the ureter, which was identified intraoperatively but not on preoperative imaging.

When comparing CTAP with operative findings among the 108 patients with a clear indication, CTAP was less likely to identify a diaphragmatic (CTAP findings, 12.0% vs. operative findings, 24.1%; $p = 0.04$) or mesenteric (5.6% vs. 18.5%, $p < 0.01$) injury (Table 2). Table 3 shows a comparison of CTAP and operative findings among those who did not have a clear indication for a laparotomy.

Abdominopelvic computed tomography and intraoperative findings were concordant in 57.0% of the study population (Fig. 1). Abdominopelvic computed tomography missed injuries in 36.2% of patients, with 18.8% of patients having a small bowel injury not appreciated on preoperative CTAP. Other missed injuries included injuries to the colon/rectum (4.7%), diaphragm (4.0%), stomach (5.4%), and the spleen (5.4%). Based on CTAP findings, three patients (2.0%) underwent a diagnostic angiogram. None underwent a therapeutic intervention at the time of angiogram. Three patients (2.0%) underwent a trial of nonoperative management based on CTAP findings. One patient had a liver injury on imaging, failed nonoperative management, and required a right hepatectomy. Two patients had no obvious intraperitoneal injuries on initial imaging. The first was found to have a small bowel injury, while the other underwent a negative laparotomy. Six patients (4.0%) had a negative laparotomy; the respective CTAPs indicated either a potential hollow viscus or vascular injury.

DISCUSSION

Imaging is a crucial adjunct that is heavily used in the assessment and management of trauma patients.[7] The utility of

TABLE 1. Patient Characteristics and Outcomes

Characteristic	All Patients (N = 149)	Clear Indication for Laparotomy (n = 108)	No Clear Indication for Laparotomy (n = 41)
Patient demographics			
Age, y	30.1 ± 11.2	30.7 ± 11.3	28.7 ± 11.1
	27 (21–36)	28 (22–36)	24 (20.5–36)
Male, n (%)	137 (91.9%)	103 (95.4%)	35 (85.4%)
Race, n (%)			
Black	131 (87.9%)	93 (86.1%)	38 (92.7%)
White	13 (8.7%)	11 (10.2%)	2 (4.9%)
Other	5 (3.4%)	4 (3.7%)	1 (2.4%)
Admission presentation			
Admission SBP, mm Hg	129.7 ± 30.4	128.8 ± 33.5	132.0 ± 20.2
	129 (110.5–149.5)	127.5 (105.5–150)	130 (120.5–145.5)
Admission HR, bpm	95.1 ± 25.5	95.8 ± 26.1	93.2 ± 24.0
	90 (75–112)	90 (75–113.5)	89 (74–110.5)
Admission GCS	14.2 ± 2.5	14.0 ± 2.7	14.6 ± 1.9
	15 (15–15)	15 (15–15)	15 (15–15)
Hypotensive on admission, n (%)	12 (8.1%)	12 (11.1%)	0
Abdominal pain present on admission, n (%)	87 (58.4%)	87 (80.6%)	0
Peritonitis present on admission, n (%)	12 (8.1%)	12 (11.1%)	0
Evisceration present on admission, n (%)	0	0	0
GSW trajectory, n (%)			
Flank	17 (11.4%)	11 (10.2%)	6 (14.6%)
Multiple	76 (51.0%)	55 (50.9%)	21 (51.2%)
Pelvic	12 (8.1%)	5 (4.6%)	7 (17.1%)
Thoracoabdominal	15 (10.1%)	11 (10.2%)	4 (9.8%)
Transabdominal	29 (19.5%)	29 (26.9%)	0
Injury scores			
Brain AIS	0.3 ± 1.0	0.2 ± 0.9	0.3 ± 1.1
	0 (0–0)	0 (0–0)	0 (0–0)
Face AIS	0.1 ± 0.4	0.1 ± 0.4	0.1 ± 0.4
	0 (0–0)	0 (0–0)	0 (0–0)
Neck AIS	0.2 ± 0.7	0.1 ± 0.7	0.1 ± 0.8
	0 (0–0)	0 (0–0)	0 (0–0)
Chest AIS	1.5 ± 1.5	1.4 ± 1.6	1.7 ± 1.5
	1 (0–3)	0.5 (0–3)	2 (0–3)
Abdomen/pelvis AIS	3.1 ± 0.9	3.1 ± 0.8	3.1 ± 1.0
	3 (3–3)	3 (3–3)	3 (2–4)
Spine AIS	0.6 ± 1.2	0.6 ± 1.2	0.6 ± 1.3
	0 (0–0)	0 (0–0)	0 (0–0)
Upper extremity AIS	0.8 ± 1.0	0.7 ± 1.0	1.1 ± 1.2
	0 (0–1.5)	0 (0–1)	1 (0–2)
Lower extremity AIS	1.3 ± 1.4	1.3 ± 1.4	1.4 ± 1.4
	1 (0–3)	1 (0–3)	1 (0–3)
ISS	22.0 ± 11.2	21.3 ± 11.6	23.8 ± 10.0
	19 (14–27)	19 (14–27)	22 (14–31)
Outcomes			
Required ICU admission, n (%)	66 (44.3%)	46 (42.6%)	20 (48.8%)
Required mechanical ventilation, n (%)	61 (40.9%)	41 (38.0%)	20 (48.8%)
Hospital LOS, d	14.6 ± 17.5	14.6 ± 15.3	14.5 ± 22.5
	9 (6–17.5)	10 (6–18.5)	7 (5–12.5)
ICU LOS, d	11.2 ± 11.0	12.0 ± 10.6	9.5 ± 11.9
	7 (4–15)	8 (5–16)	6 (4–9)
Mortality, n (%)	2 (1.3%)	2 (1.9%)	0

Hypotension at admission defined as a systolic blood pressure of <90 mm Hg.

AIS, Abbreviated Injury Scale; bpm, beats per minute; FAST, focused assessment with sonography in trauma; GCS, Glasgow Coma Scale; GSW, gunshot wound; HR, heart rate; ISS, Injury Severity Score; ICU, intensive care unit; SBP, systolic blood pressure.

TABLE 2. Comparison of Computed Tomography Findings and Operative Findings in Patients With a Clear Indication for Laparotomy

Finding	Computed Tomography Findings	Operative Findings	*p*
Bladder	5 (4.6%)	5 (4.6%)	>0.99
Diaphragm	13 (12.0%)	26 (24.1%)	0.04
Gallbladder	5 (4.6%)	0	0.06
Hollow viscus	79 (73.1%)	79 (73.1%)	>0.99
Stomach specifically	14 (13.0%)	60 (55.6%)	<0.01
Colon or rectum specifically	49 (45.4%)	49 (45.4%)	>0.99
Small bowel specifically	19 (17.6%)	13 (12.0%)	0.34
Undifferentiated	22 (20.4%)	—	—
Kidney	25 (23.1%)	17 (15.7%)	0.23
Liver	40 (37.0%)	34 (31.5%)	0.47
Liver injury intervened upon	—	25 (23.1%)	—
Mesentery	6 (5.6%)	20 (18.5%)	<0.01
Pancreas	9 (8.3%)	10 (9.3%)	0.81
Spleen	12 (11.1%)	16 (14.8%)	0.54
Ureter	0	2 (1.9%)	0.50
Vascular	5 (4.6%)	7 (6.5%)	0.77

All computed tomography findings listed reflect injuries that were either clearly identified or suspected on CTAP.

obtaining a preoperative CTAP prior to laparotomy in patients presenting with an AGSW is unknown. This study demonstrated that, while CTAP and intraoperative findings were concordant in many patients, over one third of patients had additional injuries found at the time of laparotomy, which were not previously identified or suspected on preoperative imaging. Furthermore, three patients (2.0%) underwent a laparotomy despite an attempt to observe these patients based on imaging findings. In addition, three patients (2.0%) underwent an angiogram based on imaging findings. In all three cases, the angiogram did not result in a therapeutic intervention. Preoperative CTAP did not appear to alter management or provide a benefit as a "roadmap" as CTAP often missed injuries.

For decades, all patients with transabdominal gunshot wounds were simply explored. Injuries were identified at the time of exploration and repaired, as was deemed appropriate. Absolute indications for exploration included hypotension, abdominal pain thought referable to visceral injury, peritonitis, and/or evisceration. Patients with concerning trajectories that did not have an indication for operation were observed and/or had adjunctive testing, often with diagnostic peritoneal lavage (DPL).[8]

In the early 1980s, emergence of CTAP imaging revolutionized injury evaluation for blunt trauma, allowing for organ specific injury diagnosis.[9] Before CTAP, patients were explored for a positive DPL, and the rate of nontherapeutic laparotomy was about 30%.[10,11] In 1986, Phillips et al.[12] described the use

TABLE 3. Comparison of Computed Tomography Findings and Operative Findings in Patients With No Clear Indication for Laparotomy

Finding	Computed Tomography Findings	Operative Findings	*p*
Bladder	3 (7.3%)	3 (7.3%)	>0.99
Diaphragm	10 (24.4%)	13 (31.7%)	0.62
Gallbladder	0	0	>0.99
Hollow viscus	22 (53.7%)	24 (58.5%)	0.82
Stomach specifically	7 (17.1%)	15 (36.6%)	0.08
Colon or rectum specifically	14 (34.1%)	10 (24.4%)	0.47
Small bowel specifically	6 (14.6%)	8 (19.5%)	0.77
Undifferentiated	8 (19.5%)	—	—
Kidney	8 (19.5%)	4 (9.8%)	0.35
Liver	10 (24.4%)	11 (26.8%)	0.80
Liver injury intervened upon	—	8 (19.5%)	—
Mesentery	0	4 (9.8%)	0.12
Pancreas	2 (4.9%)	3 (7.3%)	>0.99
Spleen	7 (17.1%)	10 (24.4%)	0.59
Ureter	0	0	>0.99
Vascular	3 (7.3%)	4 (9.8%)	>0.99

All computed tomography findings listed reflect injuries that were either clearly identified or suspected on CTAP.

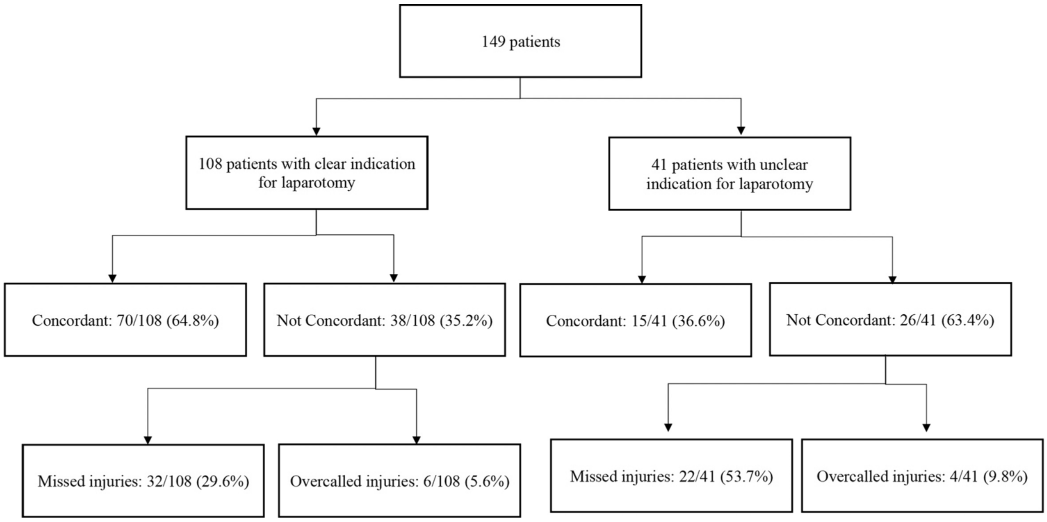

Figure 1. Concordance between CTAP findings and intraoperative findings.

of contrast-enhanced computed tomography enema in patients with penetrating trauma to the flank or back. Scans were done with oral, rectal, and intravenous contrast and were designed to only evaluate the retroperitoneal structures. To be a candidate for contrast-enhanced computed tomography enema, patients had to be stable, have no physical findings, and have a negative DPL, as it was thought that CTAP could not identify intra-abdominal injuries at the time. Contrast-enhanced computed tomography enema was found to be an accurate evaluation tool with 92% of patients managed nonoperatively if deemed to be candidates for nonoperative management based on operative findings.

Some years later, Chiu et al.[13] demonstrated that CTAP without DPL was an accurate tool to determine the presence or absence of an intra-abdominal injury following a stab wound or a gunshot wound. Abdominopelvic computed tomography became a standard test in patients with torso penetrating injury without indication for laparotomy. Expanded use of CTAP also identified injuries that could be observed, such as isolated injuries to the liver in patients who were stable.[14]

More recently, the need for surgery for blunt trauma has fallen, as many injuries previously treated with laparotomy are now observed.[15] In addition, in some municipalities, penetrating injury has become less common.[16] Thus, operative care for trauma is much less common than it has been in the past. Resident experience with operative trauma care is concerningly low.[17] It appears that CTAP has recently been used more often in patients who have indications for an operation. While not well investigated, it may be that CTAP was used to provide a "roadmap" for laparotomy. It is unclear whether surgeons who were less familiar with operative care for trauma felt the need to justify an operation, even in patients with traditional indications for laparotomy. Surgeons may also want to avoid nontherapeutic laparotomies.

If CTAP is to be used to guide an operation, an acceptable concordance rate should be determined, and thus, understanding the role of CTAP in other disease processes allows one to contextualize the findings from our study. Arruzza et al.[18] conducted a meta-analysis on the accuracy of diagnostic imaging in diagnosing appendicitis and report a sensitivity of 97.2% and a specificity of 95.6%. The sensitivity for mesenteric ischemia is 96%, while the specificity is 94%.[19] Similar values have been described for detecting high-grade bowel obstructions.[20] Given this literature, a concordance of 57% is notably lower and further questions the role of CTAP in accurately diagnosing traumatic injuries in this clinical setting.

Use of CTAP in patients with indications for laparotomy is potentially problematic for several reasons. Most importantly, patients initially stable may decompensate while waiting for a CTAP. An unnecessary CTAP increases the cost of care.[21] In addition, obtaining a CTAP may introduce additional delays to laparotomy, which may result in adverse outcomes.[22]

There are several limitations to this study that need to be acknowledged. The question will remain how often a preoperative CTAP is obtained for a "roadmap"; we do not have that data. We can only say that, anecdotally, it appears that this happens rather frequently at our institution and others as well after discussing this with colleagues. This specific question can perhaps be better investigated prospectively where the specific indication for CTAP can be discerned. The retrospective nature of this study made it difficult to ascertain the true physical examination findings and reason for CTAP. Clinical and intraoperative findings were limited by available documentation. A prospective study may be able to better capture these findings. In addition, we did not compare this cohort of patients with those who underwent a CTAP but did not undergo laparotomy. Thus, we cannot comment about the use of CTAP candidates for nonoperative management; however, we will be designing a prospective study, which should help to answer this specific question. This study was limited to one institution and theoretically may not be generalized to other institutions.

CONCLUSION

Abdominopelvic computed tomography has little utility for patients who undergo a laparotomy for an AGSW. While a CTAP scan may help to define an intra-abdominal trajectory when the trajectory is unclear, it does not alter management strategies in those with indications for an operation. In addition, CTAP missed injuries in a third of patients and contributed to all nontherapeutic laparotomies. A preoperative CTAP has minimal value in patients who have indications for an operation.

AUTHORSHIP

D.V.F. and T.M.S. contributed in the study conception and design. M.V. and N.K.D. contributed in the acquisition of data. M.V., N.K.D., D.V.F., and T.M.S. contributed in the analysis and interpretation of data. M.V., N.K.D. contributed in the literature review. M.V. contributed in the drafting of manuscript. N.K.D., D.V.F., and T.M.S. contributed in the critical revision.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D875).

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