OTA Funding Award Winner

Over-utilization of computed tomography angiography in extremity trauma

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Abstract

Objectives: Widespread availability of computed tomography angiography (CTA) for diagnosing arterial injury in injured extremities has created the possibility of overuse. The objective of this study was to evaluate CTA utilization, indications, ordering personnel, and rate of significant findings for blunt or penetrating extremity trauma at a level I trauma center.

Methods: We performed a retrospective chart review of 1440 consecutive CTAs of upper and lower extremities from 2010 to 2012 at a large level I trauma center, and included only those done for acute trauma. Data were collected with regard to injury, initial exam, reason given for ordering a CTA, specialty of physician ordering CTA, results, and vascular interventions needed. CTAs were categorized as appropriately ordered based on if there was a documented abnormal distal pulse or ankle-brachial index (ABI). Study indication was classified as inconclusive if no vascular exam was documented or physical exam varied.

Results: A total of 481 CTAs were performed after blunt or penetrating trauma in the emergency room with 31.0% appropriately indicated, 48.0% without indication, and 21.8% inconclusive. Mechanism of injury was most commonly a gunshot wound (40.3%), followed by motor vehicle accidents (39.5%). Overall, 61.5% of the studies had normal arterial flow and only 15.8% of CTAs required vascular operative intervention. Of the studies appropriately indicated, 76.5% had positive findings, with 43% needing operative intervention compared to the inappropriately indicated studies only 11.6% had positive findings, with 0.4% needing operative intervention ($P < .0001$).

Conclusion: CTA for blunt or penetrating trauma at a level I trauma center may be over-utilized. Often, this advanced imaging is ordered prior to orthopaedic evaluation or limb reduction, without exam-based indication, and most do not affect patients' treatment. From our study, CTA utilization based on more stringent exam findings at our hospital could eliminate 48% of all CTA studies for trauma.

Keywords: computed tomography angiography (CTA), extremity trauma, vascular extremity injury, vascular trauma

1. Introduction

Traumatic arterial injury can occur after blunt or penetrating trauma. Although it occurs in <1% of long bone fractures, it can occur in up to 30% of gunshot wounds (GWs)[1] and 16% of knee dislocations.[2–5] CTA is widely used for diagnosing arterial injury. Previously, conventional arteriography was the diagnostic gold standard for extremity arterial injury, though this has been largely replaced by CTA.[6–13] It can be obtained rapidly and reliably within an emergency department to evaluate patients with concern for arterial injury.[7]

Physical exam findings of arterial compromise include hard signs such as abnormal distal pulses, expanding hematoma, pulsatile bleeding, palpable thrill, or associated neurological injury.[2,7,14,15] Hard signs of vascular compromise usually necessitate urgent intervention with surgical exploration and intraoperative angiography. Soft signs of vascular injury include history of bleeding in transit, unexplained hypotension, proximity-related injury to a major vessel, nonexpanding hematoma, or nonpulsatile bleeding.[2,7,16]

Traditional orthopaedic evaluation of extremity vascular status includes documentation of pulses (palpable, dopplerable, or absent) and neurologic exam, and comparison to the contralateral extremity. The physical exam is then repeated after fracture or dislocation reduction has been completed. Factors that might influence peripheral vascular exam findings such as systemic hypotension and hemodynamic stability are taken into account during evaluation. If the vascular exam is found to be abnormal or asymmetric after limb reduction, an ankle brachial index (ABI) should be performed. Additionally, injuries with mechanisms such as GWs, knee dislocations, and comminuted tibial plateau fractures should have an ABI performed. An ABI value of <0.90 is 97% to 100% accurate in detecting arterial injury, and is thus an indication for further vascular workup.[17,18] Patients with strong or equal peripheral pulses and a normal ABI (≥0.9) can safely be treated without CTA but with serial monitoring of arterial status by physical examination.[17]

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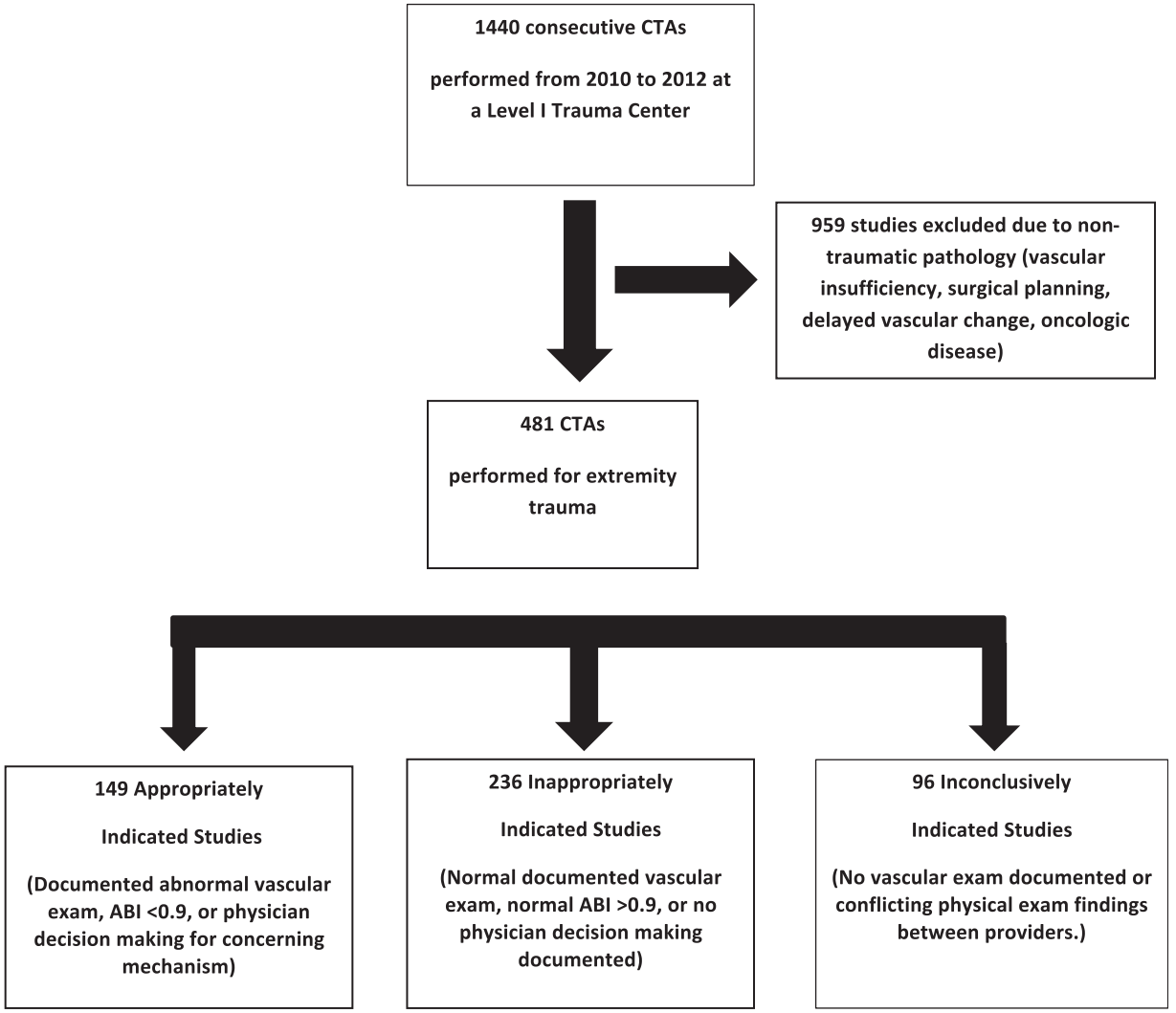

Figure 1. Flowchart with exclusion criteria and indications for ordering CTA in extremity trauma.

The objective of this study was to evaluate CTA utilization, indications, ordering personnel, and rate of significant findings for blunt or penetrating extremity trauma at a level I trauma center. We hypothesize that extremity CT angiography is frequently over-utilized in the emergency department after evaluating patients with a normal vascular exam.

2. Patients and methods

We performed a retrospective chart review of 1440 consecutive CTAs of upper or lower extremities from 2010 to 2012 at a large level I trauma center with Institutional Review Board (IRB) approval. Search was performed utilizing PACS system to identify all computed tomography angiography of the upper extremities, lower extremities, and abdomen/pelvis with lower extremity run-off within the stated time frame. Only studies performed for acute trauma in the adult emergency room setting were included. Studies were excluded if performed for peripheral vascular disease, surgical planning or delayed change in vascular exam. Two reviewers performed detailed chart reviews with an overlap of 10% of the population to ensure accuracy and consistency. Data were collected with regard to patient age, sex, injury, initial exam, documented reason for ordering a CTA, specialty of physician ordering CTA, results, and vascular interventions performed. We utilized transfer records, history and physical exams by the emergency department, the trauma team, and other consultants such as orthopaedic surgery, radiology reports, and operative reports.

2.1. Indications

Each CTA was categorized as appropriately or inappropriately ordered based on documented physical exam or medical reasoning. We utilized the established criteria set forth as hard and soft clinical signs of arterial injury in extremities[7] and ankle-brachial index (ABI) criteria.[17] Appropriate indications included abnormal distal pulses or abnormal ABI <0.90. Other appropriate indications included concern for active bleeding or clearly stated provider reasoning in regards to mechanism of injury (i.e., knee dislocation) with an abnormal ABI. Inappropriate indications included normal documented pulses or normal ABIs regardless of injury type or location, or abnormal exam prior to fracture or joint reduction. Studies were classified as inconclusively indicated if no vascular exam was documented or if physical exam findings varied between providers (Fig. 1). Each study was then categorized by mechanism of injury. We analyzed

Table 1

Patient demographics and mechanism of injury.

Total CTAs 2010–2012 performed for extremity trauma	481
Average age	36.9 years (18–91)
Median age	33
Percentage male	78.4%
Mechanism of Injury	
GSW	40.1% (193)
MVC/MCC	39.3% (189)
Penetrating wound	5.2% (25)
Fall	3.7% (18)
Automobile versus pedestrian	4.4% (21)
Crush injury	3.1% (15)
Other	4.1% (20)

MCC = motorcycle collision; MVC = motor vehicle collision.

results based on indications, mechanism of injury, and ordering providers.

2.2. Statistical analysis

Differences in ordering provider, positive angiography results, and need for surgical intervention were investigated using a chi-square test and a Student *t* test for appropriately indicated versus inappropriately indicated studies. A P value of $<.05$ was considered significant. All analyses were performed with Stata statistical software (version 11.0; StataCorp, College Station, Texas.).

2.3. Cost analysis

We gathered charge information from the medical billing department at our institution based on CPT code for each procedure. We also obtained reimbursement data from the 2012 Medicare database. Estimated healthcare savings were calculated using values from the Medicare database and the charges billed at our institution. Cost savings were determined based on inappropriately indicated CTA studies annually.

3. Results

A total of 481 consecutive CTAs of an upper or lower extremity were performed after blunt or penetrating trauma in the emergency room from 2010 to 2012. Average patient age was 36.9 years old and 78.4% male. Mechanism of injury was most commonly a GSW (40.1%), followed by motor vehicle or motorcycle accidents (39.3%) (Table 1). Based on determined criteria for appropriate CTA utilization, 31.0% were appropriately indicated, 48.0% inappropriately indicated, and 21.8% inconclusively indicated. Of the patients who received a CT angiogram, ABIs were only performed in 60 patients (12.5%) presenting to the emergency department with 28 ABIs (46.7%) found to be normal with an index > 0.9. Every patient with a normal ABI also had a normal CTA ($P < .0001$).

Overall, 61.5% (296) of the studies had normal arterial flow and only 15.8% (76) of CTAs required vascular operative intervention. Operative intervention was defined as vascular repair, ligation, or bypass; intraoperative arteriography; or amputation. Of the studies appropriately indicated, 76.5% (114) had positive findings, with 43.0% (64) needing operative intervention compared to the inappropriately indicated studies where only 11.6% (27) had positive findings, with 0.4% (1) needing operative intervention ($P < .0001$) (Fig. 2). At our institution, 81.9% of CTAs are ordered by emergency department physicians, followed by trauma surgeons (10.8%), then orthopaedic surgeons (7.3%). Of the unindicated studies, 92.2% (214)% were ordered by emergency room physicians, compared to 1.3% (3) inappropriate studies ordered by orthopaedic surgeons ($P = .0003$).

The 76 patients that required operative intervention were most commonly injured via ballistic wound (47%), motor vehicle accident (32%), or stab wound (7.3%). Only 1.5% (one patient) sustained a vascular injury via sports mechanism with a knee dislocation.

With respect to specific injury mechanism, there were 18 patients with knee dislocations. Eight (44.4%) had abnormal vascular exams, and of these, 6 (75%) had positive CTA findings (Table 2). Patients with ballistic trauma had normal vascular exams and no hard signs of vascular injury 60.6% of the time. Of

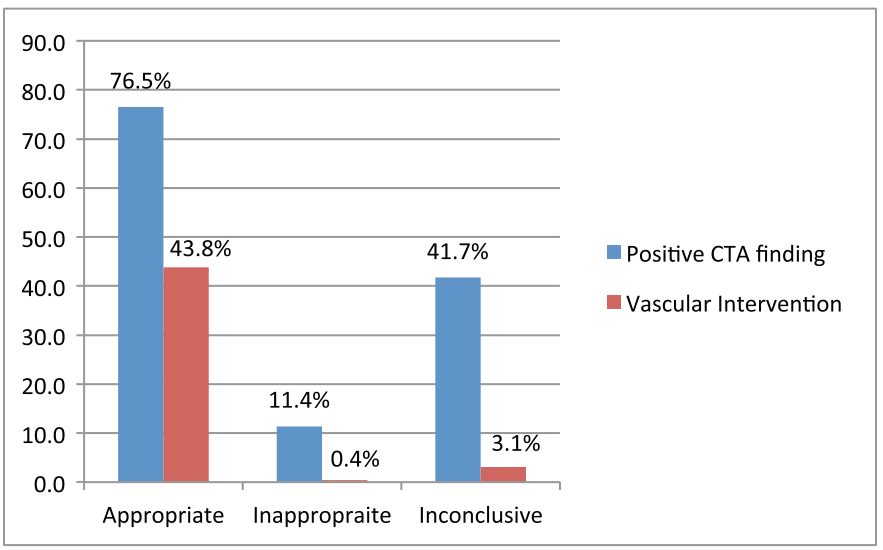

Figure 2. This depicts the frequency of positive CTA findings and frequency of operative vascular surgery intervention in studies ordered with appropriate, inappropriate, or inconclusive indications. Vascular interventions include operative vessel repair, ligation, graft or shunt; intraoperative arteriography; or amputation.

Table 2

In patients who sustain a knee dislocation, treating physicians must have a high suspicion for vascular injury with well documented vascular exam and ABI.

No.	Patient	Mechanism	Physical exam	Ordering physician	CTA results	Intervention
1	20 yoM	Auto vs pedestrian	Intermittent dopplerable PT pulse, no DP, concern for compartment syndrome	ED	Concern for popliteal extravasation	Fasciotomy, Arteriogram
2	32 yoM	MVC	No palpable or dopplerable pulse	ED	Narrowing of popliteal artery	Arteriogram, popliteal bypass
3	36 yoM	MCC	No palpable pulse	Trauma surgeon	Popliteal occlusion	Popliteal bypass
4	19 yoM	MVC	No palpable or dopplerable pulse	Orthopaedic surgeon	Popliteal occlusion	Popliteal bypass, Fasciotomy
5	17 yoM	Football injury	Dopplerable pulses; ABI = 0.7	ED	Popliteal occlusion	Popliteal bypass
6	50 yoM	MCC	No palpable pulse	ED	Posterior tibial injury	Fasciotomy
7	43 yoM	MCC	No vascular exam or ABI documented	ED	WNL	No vascular intervention
8	24 yoM	MVC	Normal vascular exam, no ABI	ED	WNL	No vascular intervention
9	23 yoF	MVC	Normal vascular exam, ABI abnormal (0.86)	ED	WNL	No vascular intervention
10	46 yoF	MVC	No palpable prior to reduction; palpable pulse following reduction; no ABI	Orthopaedic surgeon	WNL	No vascular intervention
11	27 yoM	Fall	Normal vascular exam, no ABI	ED	WNL	No vascular intervention
12	26 yoF	Fall	Normal vascular exam, no ABI	ED	WNL	No vascular intervention
13	21 yoM	Fall	Normal vascular exam, no ABI	ED	WNL	No vascular intervention
14	69 yoF	Fall	Normal vascular exam, ABI > 1	ED	WNL	No vascular intervention
15	26 yoF	Auto vs pedestrian	No palpable pulse; dopplerable PT and DP	Orthopaedic surgeon	WNL	No vascular intervention
16	21 yoM	Football injury	Normal vascular exam, ABI > 1	ED	WNL	No vascular intervention
17	40 yoM	MVC	Normal vascular exam, no ABI	ED	WNL, poor quality study	No vascular intervention
18	45 yoM	MVC	Normal vascular exam, ABI WNL (0.92)	Trauma surgeon	WNL, poor quality study	No vascular intervention

This table presents a list of patient with knee dislocation in our study and includes age, sex, mechanism, physical exam findings, CTA results, and surgical intervention.
DP = dorsalis pedis artery; ED = emergency department; MCC = motorcycle collision; MVC = motor vehicle collision; PT = posterior tibial artery; WNL = within normal limits.

the 193 GSWs, 48 (24.9%) had abnormal vascular exams, and of these, 36 (75%) had positive CTA findings and 24 (50.0%) required operative intervention. In patients with normal vascular exams, 117 (59%) studies were inappropriately ordered with only 14 (12%) having positive CTA findings and 1 (0.4%) required operative intervention ($P < .0001$). Only 1 patient with a normal vascular exam was found to have abnormalities on CTA requiring operative intervention. This patient had symmetric dopplerable pules after a ballistic injury to the thigh but was found to have transection of the superficial femoral artery requiring operative repair. However, no ABI was documented.

4. Discussion

This is the first study to examine rates of indicated CTA use with regard to physical exam, as well as determining which physicians were ordering the imaging. CT angiography for blunt or penetrating trauma at our level I trauma center may be over utilized. Often, this advanced imaging is ordered prior to orthopaedic evaluation or limb reduction, without exam-based indication, and most do not affect patients' treatment. We found at our institution studies were frequently ordered based on gross deformity or penetrating mechanism with proximity to a major vessel rather than on physical exam findings. The majority of these studies were negative in the setting of normal vascular exam. In the setting of abnormal or asymmetric distal pulses, most patients did not have an ABI documented. In the example of a knee dislocation that spontaneously reduces, a well-performed ABI is sufficient to rule out arterial injury to the popliteal vessel.[22,23] Utilization of ABI as a screening test has been proven to reduce CTAs by at least 9% in 1 trauma center.[24] CTAs performed without a high pretest probability may also lead to subtle false positive results requiring further unnecessary workup that results in increased costs, vascular consultations, and patient testing with radiation exposure.

There were several limitations to our study. Some physical exam findings differed between providers, no ABI was performed (87.5%), or no medical decision making was documented to describe the path to ordering a CTA. Injuries with pulsatile bleeding or rapidly expanding hematomas that went directly to the operating room were not captured in this study, but do not represent a large number of annual cases at our institution. Also, because we only examined patients that received a CTA we do not capture data on patients with concerning mechanisms, such as knee dislocations, that were appropriately managed with normal physical exam and ABIs. Suboptimal studies with poor contrast timing, metal artifact, or vasospasm may over-predict our rate of positive CTA results.

Several studies have shown CTA to be more time efficient, cost effective, and noninvasive compared to conventional angiography with a sensitivity of 90% to 95.1% and specificity of 98.7% to 100% for arterial injury.[7,8,20–23] Prior indications for arteriography have included trauma within proximity to a major vessel, 98% of studies performed for GSW in near proximity to a major vessel were found to be negative.[15,24] Another study revealed operative vascular injuries in only 2% of patients with ballistic long bone fractures and a normal vascular exam.[19] Our study reaffirms that in patients with ballistic injuries (with or without fracture) and a normal vascular exam, 90.1% had negative CTA imaging and 1 patient required operative intervention for a vascular injury.

A CTA at our institution is currently billed at $2593 for an upper extremity CTA and $2408 for a lower extremity CTA. Utilizing the Medicare database for standardized fee schedule in 2012, the charge for an upper extremity CTA is $404.66 and lower extremity CTA is $447.66, including both the technical and professional components.[25] If CTAs were ordered only for those with abnormal exam, our institution would have eliminated 232 studies at a conservative estimate for total savings of $93,881 (Medicare costs) to $556,800 (institute billing fees). From our study, CTA utilization based on more stringent exam findings at our hospital could save at least $31,200 – $185,600 annually in unnecessary healthcare expenditures. More importantly, overutilization of CTA leads to wasted

hospital resources. These are time-consuming studies that can overwhelm the workflow for CT scanners and radiology technicians in a busy level I trauma center. Training physicians to perform diligent vascular exams, including ABIs would decrease CTA utilization, improve resource utilization, decrease unneeded vascular consultations, and reduce unneeded patient radiation exposure.

Several studies have standardized protocols for CT angiography with the standard effective dose as 9.3 mSv.[26,27] At our institution, we utilize similar standardized protocols for each CTA. A CTA of the upper extremity estimates a total effective radiation dose of 4.5 mSv with 100 mL of Omnipaque 350 contrast agent. The current protocol for a CTA of the lower extremity estimates a total effective radiation dose of 9.6 mSv with 120 mL of Omnipaque 350 contrast agent. These estimates were made using a Monte Carlo-based dose simulator for our CT scanner and do not include the likely dose reduction that would come from the use of tube current modulation, which is part of the protocol. No evidence of acute kidney injury was noted after contrast bolus in a sample survey of the data.

Relying on proven physical exam findings or testing such as an ABI, and involving specialists early prior to ordering advanced imaging may help cut down unnecessary spending and patient risk without forfeiting patient care. Widespread availability of CTA for diagnosing arterial injury in extremity trauma has created the possibility of overuse. The value of the physical exam and a simple screening test like the ABI seem to be diminished in the face of advanced imaging and diagnostic modalities. Accordingly, this led to excessive use at our institution. When CTA is ordered as a screening test in patients with acute trauma there is a high cost to the hospital, patient and society with little benefit. We recommend that patients with acute trauma get CTAs only when indicated by ABI <0.9 or specific clinical indications.

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