Published in final edited form as:

AJR Am J Roentgenol. 2014 June ; 202(6): W580–W585. doi:10.2214/AJR.13.11216.

Utilization of angiography and embolization for abdominopelvic trauma: fourteen years' experience at a level I trauma center

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Abstract

Purpose—To evaluate the long-term trends in the use of angiography and embolization for abdominopelvic injuries.

Methods—Utilization rates for pelvic and abdominal angiography, arterial embolization, and computed tomography (CT) were analyzed for trauma patients with pelvic fractures, liver and kidney injuries admitted to a level I trauma center from 1996-2010. Multivariable linear regression was used to evaluate trends in the use of angioembolization.

Results—A total of 9,145 patients were admitted for abdominopelvic injuries. Pelvic angiography decreased annually by 5.0% (95%CI: -6.4,-3.7%) from 1996-2002 and by 1.8% (95%CI: -2.4,-1.2%) from 2003-2010. Embolization rates for these patients varied from 49% in 1997 to 100% in 2010. Utilization of pelvic CT on the day of admission increased significantly during this period. Abdominal angiography for liver and kidney injuries decreased annually by

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The authors declare no conflicts of interest.

3.3% (95%CI: -4.8,-1.8%) and 2.0% (95%CI: -4.3,0.3%) between 1996-2002 and by 0.8% (95%CI: -1.4,-0.1%) and 0.9% (95%CI: -2.0,0.1) from 2003-2010, respectively. Embolization rates ranged from 25% in 1999 to 100% in 2010 for liver injuries and from 0% in 1997 to 80% in 2002 for kidney injuries. Abdominal CT for liver and kidney injuries on the day of admission also increased.

Conclusions—A significant decrease in angiography use for trauma patients with pelvic fractures, liver and kidney injuries from 1996-2010 and a trend toward increasing embolization rates among patients who underwent angiography was found. These findings reflect a declining role of angiography for diagnostic purposes, while emphasizing the importance of angiography as a means to embolization for management.

Background

In 2011, over 42 million emergency department visits and 2 million hospital admissions were due to trauma. Injuries are the third leading cause of death across all ages and the leading cause of mortality and morbidity among individuals younger than 45 years in the United States [1]. Exsanguination is the most common cause of death among trauma patients. While surgery is often considered the definitive treatment for bleeding control, it may not always be the optimal solution for stabilization of a polytrauma patient. Specifically, arterial hemorrhage arising from pelvic fractures [2-10] and solid organ injuries [11-18] are amenable to management with angiography and embolization.

In 2001, the Eastern Association for the Surgery of Trauma (EAST) published recommendations for the use of angiography and arterial embolization for patients with pelvic fractures [19] and were subsequently reiterated in the 2011 update [10]. The authors assigned a Level 1 recommendation for angioembolization in the setting of pelvic fractures for: a) hemodynamically unstable patients with no other identifiable source of bleeding; and b) patients with active contrast extravasation on computed tomography (CT), regardless of hemodynamic status [10]. More recently, a review by Papakostidis, et al. made the same conclusions [4].

Due to the lack of randomized studies evaluating the efficacy of arterial embolization in the trauma setting, EAST guidelines offered Level 2 recommendations for angiography and embolization as first line treatment of liver injuries “for a patient who is a transient responder to resuscitation as an adjunct to potential operative intervention” [20]. While there is no such recommendation for renal and splenic injuries, several studies have demonstrated a valuable role for angiography and embolization in these setting [18, 21-26]. In addition, there has been a trend toward watchful management of these injuries by trauma centers [27].

The management of trauma patients has also evolved in recent decades due to increasing availability of advanced imaging modalities such as computed tomography (CT). Multiple studies have demonstrated long-term trends with the increasing use of CT in the emergency and trauma setting [28-32]. Since angiography serves both diagnostic and therapeutic purposes, these changes in CT utilization could affect angiography utilization, should CT replace the diagnostic function of angiography. However, this potential substitution effect has not been studied previously.

Little is known about practice patterns and the actual role that angiography plays in the trauma setting. The purpose of this study was to investigate the long-term trends in utilization of angiography and embolization for trauma patients admitted at a major level I trauma center. A secondary purpose of this study was to determine if changes in CT utilization had an effect on the use of angiography. We also hypothesized that increasing CT use would have an effect of dampening the growth in angiography utilization.

Materials and Methods

This was an Institutional Review Board approved retrospective cohort study of all trauma patients hospitalized at a level I pediatric and adult trauma center over a 14-year period, with waiver of informed consent. With 5,000-6,000 annual trauma admissions, this trauma center is one of the largest in the country.

Data source and definitions

The institution's prospectively acquired trauma registry was linked to billing data. The trauma registry provided detailed information regarding patients' demographics, type and mechanism of injury, injury severity, length of hospital and intensive care unit (ICU) stay and final disposition, including mortality. Billing data provided Common Procedural Terminology (CPT) codes for procedures performed, including angiography, arterial embolization and CT scan.

All hospitalized trauma patients with pelvic fractures, liver or kidney injuries from June 1996 to June 2010 were included in the overall cohort. These groups were not exclusive, since a patient could suffer from more than one body region injury. Pelvic fractures were identified with the International Classification of Disease, Revision 9 (ICD-9) codes of 808.x; liver injuries were defined as ICD-9 codes of 864.x and kidney injuries were defined as ICD-9 codes of 866.x. Splenic injuries were not included in this study, as these patients are rarely managed with embolization at this institution.

For counts of utilization, all catheter angiography procedures performed in an arterial bed of pelvis for patients with pelvic fracture and abdomen for patients with liver and renal injuries were included in the analyses. Embolization rates are reported as a percentage of patients who underwent angiography for each type of injury. There are no unique CPT code(s) to differentiate between embolization performed for management of pelvic fractures, liver injuries or renal injuries. In order to evaluate embolization trends for liver or renal injuries alone, patients with concomitant pelvic fracture are excluded. In addition, for liver injuries we also excluded patients with concomitant renal injuries and for renal injuries, we also excluded patients with concomitant liver injuries.

CT scans were counted if they were performed within the first day of admission. Data on imaging performed at outside hospitals for transferred patients were not included in the billing department data. As a result, CT use in the first day of admission is underestimated due to lack of access to outside imaging.

Statistical analysis

Student's *t*-test with unequal variances was used to compare continuous variables while the Chi-square test was used to compare categorical variables between patients with abdominopelvic injuries who were evaluated with angiography versus those who were not.

In order to evaluate the crude change in the use of angiography over the study period, we plotted the proportion of patients who received angiography against the year of admission for each injured body part. Multivariable linear regression was used to adjust estimates for potential confounding variables on a per-patient level which were defined *a priori*: age, gender, type and mechanism of injury, injury severity, length of hospital and ICU stay and final disposition. Year of admission was included in the model to evaluate the significance of the change in utilization rate over the study period. The coefficient of the variable for year thus represents the average annual change in proportion of patients receiving a procedure over the study period.

Visual inspection of our data plots suggested that there were two separate time periods within the study period, each with a distinct linear trend. Preliminary bivariate analyses confirmed that the trends in the use of angiography decreased at a greater rate from 1996-2002 compared to 2003-2010. Therefore, the study was divided into the two time periods: 1996-2002 and 2003-2010, and separate linear regression analyses for angiography and embolization for each injured body part were performed. To assess if changes in angiography utilization were due to CT use over the time period, each model was then adjusted for the use of CT in the relevant body region. For example, use of CT pelvis (with and/or without contrast) was included in the model that evaluated the association between pelvic angiography and year of admission.

To evaluate the trends in use of embolization, the regression analysis was repeated with embolization as the main outcome variable. However, in these analyses, only patients who underwent angiography were included.

Finally, we evaluated the trends in the use of CT in the first day of admission in a similar fashion for each injured body part. As previously described, we excluded patients transferred from other acute care facilities, since robust counts of imaging obtained prior to transfer were unavailable.

Statistical significance of all tests was set at a two-tail *p* value less than 0.05. All analyses were conducted using STATA 12.0 (StataCorp, College Station, TX).

Results

A total of 76,431 trauma patients were hospitalized during the 14-year study period. Figure 1 summarizes the annual distribution of abdominopelvic injuries. Pelvic fractures, liver, and renal injuries comprised 8, 4 and 2% of the injuries, respectively. These proportions remained relatively unchanged over time.

Table 1 compares the demographic and injury-related characteristics of the 9,145 patients with abdominopelvic injuries who received angiography versus those who did not. Overall,

patients who underwent angiography had higher injury severity score, longer length of hospital stay and higher mortality, compared to those not undergoing angiography.

Pelvic fractures

A total of 6,315 patients had pelvic fractures (average of 451 per year; Figure 1) with no substantial change during the study period (7-10%).

Figure 2 demonstrates the unadjusted trend in proportion of patients with pelvic fractures who underwent pelvic angiography. The use of pelvic angiography decreased from 31% in 1996 to 9% in 2010. Multivariable model adjusting for previously mentioned confounding variables demonstrated that the proportion of patients receiving pelvic angiography decreased on average by 5.0% per year (95% CI: -6.4, -3.7%, $p<0.01$) between 1996 and 2002 and decreased by 1.8% per year (95% CI: -2.4, -1.2%, $p<0.01$) between 2003 and 2010 (Table 2). For the patients who underwent pelvic angiography without concomitant liver or kidney injuries ($n=430$), the embolization rate varied from 49% ($n=33$ out of 68) of patients admitted in 1997 to 100% ($n=14$ out of 14) admitted in 2010 (Figure 3). Multivariable regression analysis demonstrated non-significant 1.0% per year decrease in embolization from 1996 to 2002 (95% CI: -3.8, 1.9%; $p=0.504$) and non-significant 0.7% per year decrease from 2003 to 2010 (95% CI: -3.5, 2.1; $p=0.627$).

The proportion of non-transferred patients receiving a pelvic CT during the day of admission increased from 50% in 1996 to 77% in 2003; since then, a relatively steady increase has occurred, up to a rate of 89% in 2010 (Figure 4). Multivariable analysis demonstrated that the proportion of patients receiving a CT of the pelvis increased on average by 4.0% per year (95% CI: 2.1, 5.9%; $p<0.01$) from 1996 to 2002 and increased by 3.1% per year (95% CI: 2.1, 4.1; $p<0.01$) from 2003 to 2010. The observed utilization pattern for angiography was not significantly affected by the use of pelvic CT (Table 2)

Liver injuries

2,747 patients with liver injuries with or without other concomitant abdominopelvic injuries were admitted (average of 196 per year) during the study period (Figure 1). The proportion of patients with liver injuries varied from 3 to 5% per year with no significant annual change over the study period.

In this population, the use of abdominal angiography decreased from 19% in 1996 to 6% in 2010 (Figure 2). Multivariable model adjusting for potential confounders demonstrated that the proportion of patients who underwent abdominal angiography decreased on average by 3.3% per year (95% CI: -4.8, -1.8%, $p<0.01$) between 1996 and 2002 and decreased by 0.8% per year (95% CI: -1.4, -0.1%, $p=0.03$) between 2003 and 2010 (Table 2).

Among 275 patients with liver injuries who underwent abdominal angiography, 47% ($n=129$) also underwent pelvic angiography. For the evaluation of the trend in use of embolization for liver injuries, these 129 patients were excluded. As a result, we included 146 patients with liver injuries who underwent abdominal angiography with no concomitant pelvic angiography. Among these 146 patients the embolization rate varied from 25% for

those patients admitted in 1999 to 100% of patients admitted in 2010 (4 out of 4 patients) (Figure 4).

CT use during the day of admission for non-transferred patients with liver injuries increased from 20% in 1996 to 70% in 2010. Multivariable regression analysis demonstrated that the proportion of patients with liver injuries who received a CT in the day of admission increased on average by 3.3% per year (95% CI: 1.0, 5.6, $p<0.01$) from 1996-2002 and 2.8% (95% CI: 1.3, 4.2%, $p<0.01$) per year from 2003-2010. Similar to the results seen with pelvic fractures, abdominal angiography utilization rate was not significantly affected by adjustment for CT use (Table 2).

Renal injuries

From 1996-2010, a total of 1,419 patients with renal injuries were evaluated (average of 101 patients per year; Figure 1). Patients with renal injuries as a proportion of all trauma patients has not changed substantially during the study period and ranged from 2 to 3%.

The use of angiography for renal injuries decreased from 20% in 1996 to 6% in 2010 (Figure 2). Multivariate regression analysis adjusting for previously noted variables demonstrated that the proportion of patients who underwent angiography decreased by 2.0% (95% CI: -4.3, 0.3%; $p=0.09$) from 1996 to 2002 and 0.9% (95% CI: -2.0, 0.1; $p=0.09$) from 2003 to 2010. However, these decreases were not statistically significant (Table 2).

Among 171 patients with renal injuries who underwent abdominal angiography, only 101 (59%) did not undergo concomitant pelvic angiography. The embolization rate for this group varied from 0% of patients admitted in 1997 (0 of 6) to 80% of those admitted in 2002 (4 out of 5 patients) (Figure 4).

For non-transferred patients with renal injuries, CT abdomen use on the day of admission increased from 39% in 1996 to 58% in 2010. Multivariate regression analysis demonstrated that the proportion of patients with renal injuries who received an abdominal CT increased on average by 4.0% per year (95% CI: 0.2, 7.7, $p=0.037$) from 1996-2002 and 1.5% (95% CI: -0.7, 3.6%, $p=0.174$) from 2003-2010. Similar to pelvic fractures and liver injuries, the observed trend in the use of angiography for renal injuries was not significantly affected by abdominal CT use (Table 2).

Discussion

This study found a significant decrease in the use of angiography between 1996-2010, with a larger rate of decrease in the early part of the study period from 1996-2002. This trend was seen across all injury types studied. However, probably due to small sample size, some trends did not reach statistical significance.

The cause for the decrease in utilization is likely multifactorial. First, with the advancement in the quality, speed, and availability of CT, angiography likely plays a smaller role in modern practice in the diagnosis of arterial hemorrhage. Consistent with reports by other investigators [28-30], our study demonstrated a significant increase over time in the

utilization of CT. However, after adjustment for CT use in multivariate models, a significant decreasing trend for angiography utilization remained. This suggests that increasing CT use is only a small factor affecting the trends seen with angiography.

Improved patient selection for angiography may also have been a factor contributing to decreased utilization. The EAST first published guidelines for the management of hemorrhage in patients with pelvic fractures in 2001; these guidelines included recommendations for the indications for angiography that were subsequently reiterated in the 2011 update [10]. The same group published the first set of guidelines for the management of hepatic injuries in 2003; an update in 2012 gave similar recommendations for the role of angiography [20]. Prior to these initial publications, there were no widely accepted practice guidelines in the United States. If these guidelines provided more clarity about which patients are appropriate to undergo angiography, angiography use would be limited to more highly selected patients as the guidelines became incorporated into practice over time. This is supported by angiography use in 30% of patients with pelvic fractures in earlier years of this study versus 3-10% in the later years. Based on available literature, the range seen in the later years are more on par with expected angiography rates for bleeding control purposes in patients with solid organ injuries [10]. Additionally, we found an increase in the unadjusted embolization rate over time for those patients who underwent angiography. This would be consistent with more highly selected patients being referred for angiography, with the primary purpose of angiography as a means to therapeutic embolization. Obviously our study was not designed to elucidate all potential factors, for the long-term trends we observed.

This study has certain limitations. First, we focused on a single, high-volume, level I trauma center. As a result, the results of this study may not be generalizable to other settings. Second, due to the use of data from a long study period (14 years), it is possible that some of the results are influenced by changes in the coding schemes or inconsistencies in the data collection process. Third, we did not have access to the exact time of admission and time of CT scan. As a result, some of the CTs that were obtained on the day of admission could have been obtained following angiography, thereby diluting the potential substitution effect of CT. Finally, we were not able to evaluate the hospital and provider-related factors that could influence utilization pattern. A particular strength of this study is that by including patient-level data, we were able to adjust our estimates for demographic and clinical factors that could potentially influence resource utilization.

In conclusion, this study demonstrated a significant decrease in the use of angiography for trauma patients with pelvic fractures, liver and kidney injuries between 1996 and 2010. However, among patients who underwent angiography, there was a trend toward increasing rates of embolization. During the same time period, we observed a statistically significant increase in the use of pelvic and abdominal CTs. These findings reflect decreasing importance of angiography for diagnosis and an increasingly focused role of angiography as a means to therapeutic embolization for the management of patients with abdominopelvic injuries.

Acknowledgments

This research was partially supported by NIH Grant #R01-AA017497.

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Figure 1.

Annual number of patients with pelvic fractures, liver or renal injuries, 1996-2010^a

^a Only the second half of 1996 and the first half of 2010 are included in the study.

Figure 2.
Utilization of angiography for patients with pelvic fractures, liver and kidney injuries, 1996-2010

Figure 3.

Embolization rate for trauma patients undergoing angiography for pelvic fractures, liver or kidney injuries, 1996-2010^a

^a Patients with concomitant liver or kidney injuries are excluded from trend evaluations for pelvic fractures and patients with concomitant pelvic angiography are excluded from trend evaluations for liver and kidney injuries.

Figure 4.

Utilization of CT pelvis for pelvic fractures and CT abdomen for liver and kidney injuries during the first day of admission, 1996-2010^a

^a Patients transferred from other acute care facilities are excluded from these analyses

Table 1

Demographic and injury-related characteristics of trauma patients with abdominopelvic injuries based on angiography status

	Angiography n=1,300	No angiography n=7,845	p-value
Age (%)			
<14	49 (4)	518 (7)	0.002
15-18	119 (9)	698 (9)	
19-54	851 (66)	4,995 (64)	
55+	279 (21)	1,624 (21)	
Sex (%)			0.872
Male	865 (67)	5,202 (66)	
Female	435 (33)	2,643 (34)	
Race (%)			0.035
White	979 (83)	5,816 (81)	
Black	66 (6)	515 (7)	
Native American	26 (2)	134 (2)	
Asian	80 (7)	405 (6)	
Other	31 (3)	268 (4)	
Injury severity score (%)			<0.001
0-8	28 (2)	1,160 (15)	
9-15	145 (11)	2,174 (28)	
16-25	284 (22)	1,946 (25)	
25-40	477 (37)	1,719 (22)	
41-75	366 (28)	841 (11)	
Mechanism of injury (%)			
Motor vehicle collision	586 (45)	3,163 (40)	0.001
Fall	165 (13)	1,543 (20)	<0.001
Length of hospitalization, (days)	21	10	<0.001
Transferred patients (%)	502 (39)	4,041 (52)	<0.001
In hospital mortality (%)	213 (16)	591 (8)	<0.001

Table 2Multivariable linear regression evaluating the trend in the use of angiography, embolization and CT use ^{a, b}

<i>Injury type</i>	1996-2002 Average annual change (95% CI)	2003-2010 Average annual change (95% CI)
Pelvic fractures		
Pelvic angiography	-5.0 (-6.4, -3.7) ^c	-1.8 (-2.4, -1.2) ^c
Pelvic angiography, also adjusted for CT use	-4.7 (-6.1, -3.3) ^c	-1.8 (-2.4, -1.2) ^c
Pelvic embolization	-1.0 (-3.8, 1.9)	-0.7 (-3.5, 2.1)
Pelvic CT ^d	4.0 (2.1, 5.9) ^c	3.1 (2.1, 4.1) ^c
Liver injuries		
Abdominal angiography	-3.3 (-4.8, -1.8) ^c	-0.8 (-1.4, -0.1) ^c
Abdominal angiography, also adjusted for CT use	-3.1 (-4.7, -1.6) ^c	-0.7 (-1.4, -0.1) ^c
Abdominal CT ^d	3.3 (1.0, 5.6) ^c	2.8 (1.3, 4.2) ^c
Kidney injuries		
Abdominal angiography	-2.0 (-4.3, 0.3)	-0.9 (-2.0, 0.1)
Abdominal angiography, also adjusted for CT use	-1.8 (-4.1, 0.5)	-0.9 (-2.0, 0.1)
Abdominal CT ^d	4.0 (0.2, 7.7) ^c	1.5 (-0.7, 3.6)

CI, confidence interval; CT, computed tomography

^a All models adjusted for age, gender, mechanism of injury, injury severity score, length of hospital and ICU stay and final disposition.^b Point estimates represent % yearly change in proportion of patients undergoing each procedure.^c $p < 0.05$ ^d CTs performed during the first day of admission, only for non-transferred patients.