Observational Study

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Pediatric solid organ injury – frequency of abdominal imaging is determined by the treating department

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Abstract

To investigate the use of abdominal CT scanning in the management of pediatric blunt abdominal trauma in pediatric and non-pediatric departments.

In this observational cohort study, anonymized data were extracted from 2 large German statutory health insurances (~5.9 million clients) in a 7-year period (2010–2016). All patients with inpatient International Classification of Diseases (ICD) codes S36.- and S37.- (injury of intra-abdominal organs; injury of urinary and pelvic organs) aged ≤18 years were included. Demographic and clinical data were analyzed by logistic regression analysis for associations with the use of abdominal CT.

A total of 524 children with blunt abdominal trauma (mean age 11.0 ± 5.2 years; 62.6% males) were included; 164 patients (31.3%) received abdominal CT-imaging. There were no significant differences in traumatic non-intraabdominal comorbidity patterns (injuries of external causes; injuries to the head or thorax). There was substantial variability in the rate of abdominal CT imaging among different medical disciplines ranging from 11.6% to 44.5%. Patients admitted to pediatric departments (Pediatrics and Pediatric Surgery) underwent abdominal CT imaging significantly less frequently (19.7%; N = 55) compared to patients treated in non-pediatric departments (General/Trauma Surgery: 44.5%; N = 109) irrespective of concomitant injuries. The estimated OR for the use of abdominal CT by General/Trauma Surgery was 6.2-fold higher (OR: 6.15 [95-%-CI:3.07–13.21]; *P* < .001) compared to Pediatric Surgery. Other risk factors associated with the use of abdominal CT were traumatic extra-abdominal comorbidities, increasing age, male gender, and admission to a university hospital.

Abdominal CT imaging was significantly less frequently used in pediatric departments. The substantial variability of the abdominal CT rate among different medical disciplines and centers indicates a potential for reduction of CT imaging by implementation of evidence-based guidelines. Furthermore, our study underlines the need for centralization of pediatric trauma care in Germany not only to improve patient outcome but to avoid radiation-induced cancer mortality.

Abbreviations: AOK = Allgemeine Ortskrankenkasse "(one of the largest health insurance funds in Germany, insuring more than 25 million people overall consisting of eleven independent AOKs covering the area of one or several federal states)", CT = computed tomography, GPS = Good Practice Secondary Data Analysis, IAI = intra-abdominal injury, ICD = International Classification of Diseases, ICD-10-GM = International Classification of Diseases in its 10th version, German Modification, ICPM = International

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

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Classification of Procedures in Medicine, IRB = institutional review board, MRI = Magnetic Resonance Imaging, OPS = Operationen- und Prozedurenschlüssel (ICPM, German Modification), OR = odds ratio.

Keywords: claims data, CT-imaging, pediatric blunt abdominal trauma, pediatric departments, pediatric solid organ injury

1. Introduction

Trauma is the leading cause of death in children older than 1 year of age.[1,2] Over 90% of injuries are caused by blunt mechanisms.[1,2] Cross-sectional abdominal imaging with computed tomography (CT) is currently considered the gold standard for the diagnosis of suspected intra-abdominal injury (IAI) in adults and children.[3] Abdominal CT is highly reliable in ruling out IAI, with recent studies showing negative predictive rates greater than 99% after normal CT.[4] The use of CT has increased dramatically in the past 2 decades.[5,6] Moreover, 2 recent studies suggested that “whole-body” CT scanning leads to better survival compared to selective scanning in trauma patients. This may result in additional increase of abdominal CT usage in children.[7,8] However, the potential long-term consequences of radiation exposure in children requires a judiciously use of this imaging modality in children.[9,10] Children are very susceptible to developing malignancies secondary to ionizing radiation because they are more radiosensitive (owing to the presence of rapidly dividing cells in their bodies) and their longer lifespan throughout a malignancy may manifest.[9,11] Although there is no upper dose limit at the individual level, there are diagnostic reference levels (DRLs) which provide orientation and should not be exceeded in the regular case. However, while following these DRLs CT imaging should be replaced by MRI whenever possible in children.[12] Therefore, in this observational cohort study, we analyzed the use of abdominal CT scanning in the management of pediatric blunt abdominal trauma in pediatric and non-pediatric departments.

2. Methods

The study was approved by the local institutional review board (IRB 00001750). Anonymized data of a 7-year period (2010–2016) were retrospectively extracted from 2 German statutory health insurance funds: AOK Plus – Die Gesundheitskasse für Sachsen und Thüringen (~3.1 million clients) and AOK Niedersachsen (~2.8 million clients). Diagnosis and procedures were made based on the German modification of International Classification of Diseases in its 10th version (ICD-10-GM) and on the International Classification of Procedures in Medicine (ICPM). Participating researchers confirmed standards of data protection according to the Good Practice Secondary Data Analysis (GPS).[13] All patients aged $\leq$18 years with inpatient ICD-10-GM code S36 or S37 and their subdivisions (injury of intra-abdominal organs; injury of urinary and pelvic organs) who had been continuous members of their statutory health insurance for at least 1 year after their index diagnosis and with only 1 inpatient stay due to the index diagnosis during this 1 year index period were included. According to the ICPM the study population was further divided into 4 subgroups: “Computed Tomography (CT)” of the abdomen (OPS code 3–207 or 3–225), “Magnetic Resonance Imaging (MRI)” of the abdomen (OPS code 3–804 or 3–825), “CT and MRI” and “no abdominal imaging”. Patient characteristics such as age, gender, type of department (pediatrics, pediatric surgery, general/trauma surgery, general medicine), type of hospital (university hospital/non-university hospital), imaging modality (CT, MRI, CT or MRI, CT&MRI, none), length of hospital stay, and comorbidity (injuries of external causes; injuries to the head and/or injuries to the thorax) were evaluated. Data were analyzed using descriptive statistics as well as multivariate regression methods. To investigate the relationship between categorical variables Chi-Squared test or Fisher exact test were used and for continuous variables Mann–Whitney *U* test or Kruskal-Wallis test. Demographic and clinical data were analyzed by logistic regression for the use of abdominal imaging (independent variables: age, gender, length of hospital stay, type of department, university vs non-university hospital and comorbidity). The reported coefficients are Odds Ratios. Finally, the Levene-Test and check for multicollinearity by variance inflation factor were used. Statistical analysis was performed using R version 3.6.1.[14]

3. Results

A total of 524 children with blunt abdominal trauma (mean age 11.0 ± 5.2 years; 62.6% males) were included. Treatment was provided by different medical departments: Pediatrics (28.6%; N = 150), Pediatric Surgery (24.6%;N = 129), General/Trauma Surgery (46.8%;N = 245), and General Medicine (2.1%;N = 11). Due to exceptionally low patient numbers, children treated by General Medicine were excluded from further analysis for reasons of data protection and lack of statistical power. The mean length of stay of all patients was 10.2 ± 19.1 days; 94 (17.9%) individuals were treated at a university hospital. There were no significant differences in traumatic non-intraabdominal comorbidity patterns (injuries of external causes; injuries to the head or thorax; Table 1). Patients admitted to pediatric departments (Pediatrics and Pediatric Surgery) underwent abdominal cross-sectional imaging (CT or MRI) significantly less frequently (25.8%) compared to patients treated in non-pediatric departments (General/Trauma Surgery 46.9%; $P < .0001$) (Table 1). The rate of abdominal CT scans was 19.7% (N = 55) in pediatric departments (Pediatrics: 26.7%; N = 40, Pediatric Surgery: 11.6%; N = 15) versus 44.5% (N = 109) in non-pediatric departments (General/Trauma Surgery; Table 1). Logistic regression confirmed a significantly higher odds ratio (OR) for utilization of abdominal imaging (CT or MRI) by General/Trauma Surgery (OR: 4.82 [95%CI:2.55–9.58]; $P < .001$; Table 2a; supplementary Table 2b, http://links.lww.com/MD/F138). The estimated OR for the use of abdominal CT by General/Trauma Surgery was 6.2-fold higher (OR: 6.15 [95%-CI:3.07–13.21]; $P < .001$) compared to Pediatric Surgery (Tables 3 and 4). Other factors associated with the use of abdominal CT included increasing age, male gender, length of hospital stay, admission to a university hospital (vs non-university hospital), and traumatic non-intraabdominal comorbidity (Tables 3 and 4). Analysis of different age groups showed

Table 1

Patient characteristics.

	All departments	Pediatric Departments	Non-Pediatric Departments	$P^{\dagger}$	Pediatrics	Pediatric surgery	General surgery	$P^{\ddagger}$
Total patients [n (%)]	524	279 (53.2)	245 (46.8)		150 (28.6)	129 (24.6)	245 (46.8)	
Sex								
Female [n (%)]	196 (37.4)	113 (40.5)	83 (33.9)	.1407	63 (42.0)	50 (38.8)	83 (33.9)	.2521
Male [n (%)]	328 (62.6)	166 (59.5)	162 (66.1)		87 (58.0)	79 (61.2)	162 (66.1)	
Mean age (years)	11.0 ± 5.2	8.5 ± 4.9	13.9 ± 3.9	<.0001	9.0 ± 5.0	7.9 ± 4.7	13.9 ± 3.9	<.0001
Age [years]								
≤ 5 [n (%)]	96 (18.3)	84 (30.1)	12 (4.9)	<.0001	38 (25.3)	46 (35.7)	12 (4.9)	<.0001
6 to 11 [n (%)]	157 (30.0)	106 (38.0)	51 (20.8)	<.0001	58 (38.7)	48 (37.2)	51 (20.8)	.0001
12 to 18 [n (%)]	271 (51.7)	89 (31.9)	182 (74.3)	<.0001	54 (36.0)	35 (27.1)	182 (74.3)	<.0001
Type of hospital								
University hospital [n (%)]	94 (17.9)	71 (25.4)	23 (9.4)	<.0001	12 (8.0)	59 (45.7)	23 (9.4)	<.0001
Non-University hospital [n (%)]	430 (82.1)	208 (74.6)	222 (90.6)		138 (92.0)	70 (54.3)	222 (90.6)	
Imaging								
CT [n (%)]	164 (31.3)	55 (19.7)	109 (44.5)	<.0001	40 (26.7)	15 (11.6)	109 (44.5)	<.0001
MRI [n (%)]	34 (6.5)	25 (9.0)	9 (3.7)	.0230	16 (10.7)	9 (7.0)	9 (3.7)	.0228
CT or MRI [n (%)]	187 (35.7)	72 (25.8)	115 (46.9)	<.0001	51 (34.0)	21 (16.3)	115 (46.9)	<.0001
CT & MRI [n (%)]	11 (2.1)	8 (2.9)	3 (1.2)	.2326	5 (3.3)	3 (2.3)	3 (1.2)	.3307
Without	337 (64.3)	207 (74.2)	130 (53.1)	<.0001	99 (66.0)	108 (83.7)	130 (53.1)	<.0001
Mean length of hospital stay [days]	10.2 ± 19.1	11.5 ± 24.7	8.8 ± 8.9	.1653	10.1 ± 14.4	13.1 ± 32.8	8.8 ± 8.9	.0205
Comorbidity								
traumatic non-intraabdominal-comorbidity *	359 (68.5)	189 (67.7)	170 (69.4)	.7562	97 (64.7)	92 (71.3)	170 (69.4)	.4525
traumatic non-abdominal-comorbidity: head trauma & thoracic trauma **	233 (44.5)	126 (45.2)	107 (43.7)	.7996	65 (43.3)	61 (47.3)	107 (43.7)	.7573

† Pediatric Departments vs Non-Pediatric Departments.
‡ comparison between the different departments.
* aggregation of ICD-10-GM S00-T14 excl. S36/S37, injury of external causes.
** aggregation of ICD-10-GM S00-S09 and/or S20-S29, injuries to the head & injuries to the thorax.
Characteristics of 524 patients with ICD-10-GM code S36 or S37 (injury of intra-abdominal organs; injury of urinary and pelvic organs) aged ≤ 18 years.
CT = computed tomography, MRI = magnetic resonance imaging, ICD-10-GM = International Classification of Diseases in its 10th version, German Modification.

that the chance to undergo an abdominal CT increased 1.4-fold in patients aged 6 to 11 years and 3.4-fold in children older than 11 (12–18) years (Table 3). Additionally, the analysis of data regarding the use of MRI as imaging modality (MRI imaging: 6.5%; N=34) showed significant differences between pediatric (9.0%;N=25) and non-pediatric departments (3.7%; N=9; P=.023) (Table 1). Due to lack of statistical power further subgroup analysis demonstrated no significant differences for the use of abdominal MRI between all departments compared to Pediatric Surgery (data not shown; supplementary Table 5a, http://links.lww.com/MD/F139, and Table 5b, http://links.lww.com/MD/F140).

4. Discussion

In this observational cohort study, we set out to evaluate the usage of abdominal imaging (CT, MRI) in the management of children and adolescents with blunt abdominal trauma in pediatric and non-pediatric departments. We used the database of 2 large German statutory health insurance funds, which included ~5.9 million clients. Therefore, we were able to analyze a representative number of patients. In previous studies of our own group, we have demonstrated that claims data are an appropriate source of evidence for pediatric health services research.[15–17]

Table 2

A Estimated odds ratios for use of CT or MRI vs no CT or MRI.

	OR	95%-CI	P
Age			
6 to 11	1.98	1.01–4.05	.053
12 to 18	3.32	1.73–6.70	<.001
Male gender	1.49	0.99–2.25	.058
Length of hospital stay	1.02	1.01–1.04	.011
Pediatrics	3.98	2.05–8.06	<.001
General surgery	4.82	2.55–9.58	<.001
Admission to university hospital	1.97	1.07–3.69	.031
Traumatic non-intraabdominal-comorbidity*	2.53	1.63–3.98	<.001

* aggregation of ICD-10-GM S00-T14 excl. S36/S37, injury of external causes.
CI = confidence interval, ICD-10-GM = International Classification of Diseases in its 10th version, German Modification, OR = odds ratios, reference categories: ≤ 5, Female, Pediatric surgery, non-university hospital.

Table 3

Estimated odds ratios for use of CT vs no CT.

	OR	95%-CI	P
Age [years]			
6 to 11	1.39	0.67–3.03	.391
12 to 18	3.35	1.68–7.08	<.001
Male gender	1.59	1.04–2.46	.035
Length of hospital stay	1.02	1.00–1.03	.039
Pediatrics	4.21	2.02–9.28	<.001
General surgery	6.15	3.07–13.21	<.001
Admission to university hospital	2.09	1.09–4.05	.026
Traumatic non-intraabdominal-comorbidity*	2.39	1.51–3.86	<.001

* Aggregation of ICD-10-GM S00-T14 excl. S36/S37, injury of external causes.
CI = confidence interval, ICD-10-GM = International Classification of Diseases in its 10th version, German Modification, OR = odds ratios, reference categories: ≤5, Female, Pediatric surgery, non-university hospital.

4.1. Adult trauma centers treat the majority of children with blunt abdominal trauma

The clinical assessment of children with blunt abdominal trauma can be challenging due to age related physiologic and developmental parameters, alterations in mental status, and a lower comfort level of medical providers unexperienced in taking care of pediatric patients.[3] In our study 47% of the patients were treated in non-pediatric trauma centers and 45% of these children underwent abdominal imaging by CT. This is in line with other studies showing that the majority of children with blunt abdominal trauma present to adult trauma centers and more than half of them undergo abdominal CT as part of their trauma evaluation.[18,19]

4.2. Variability in the use of abdominal CT indicates a potential for reduction of CT imaging

Our study showed a great variation in the rate of abdominal CT imaging among different medical disciplines ranging from 11.6% to 44.5% (Table 1) which is well in line with data of other centers.[3] At the same time, the substantial variability in the rate of abdominal CT scans indicates a potential for reduction of CT imaging by implementation of evidence-based guidelines.[3] There are several guidelines for the identification of children with low and very low risk for IAI in whom abdominal CT scanning can be safely avoided.[18,20] However, the variability of CT usage among different centers shows that physicians do not consistently apply evidence-based decision instruments in their daily practice.[21]

4.3. Pediatric trauma centers use abdominal CT less frequent than adult trauma centers

Patients admitted to pediatric departments (Pediatrics and Pediatric Surgery) underwent abdominal CT imaging significantly less frequently compared to patients treated in non-pediatric departments (Table 1). Physicians treating children on a daily basis may have a higher awareness of the potential long-term consequences of radiation exposure and the associated increased risk of cancer mortality. Moreover, pediatric departments usually collaborate with pediatric radiologists who ensure that radiation is limited to a minimum. The chance that a patient underwent abdominal CT was 6-fold higher if the patient was treated in an adult surgery department compared to a pediatric surgery department (Table 3).). It should be noted that the average age for patients with CT is higher, even within the age groups, for patients treated in non-pediatric departments what could have an impact on the treatment (Table 5). However, logistic regression analysis confirmed an age-independent (age: independent variable) significantly higher odds ratio for utilization of abdominal imaging by General/Trauma Surgery compared to Pediatric Surgery (OR: 4.82 [95%CI:2.55–9.58]; $P<.001$; Table 2a). At the same time, there were no significant differences in the traumatic non-intraabdominal comorbidity patterns (Table 1). However, additional head and/or thoracic trauma increased the likelihood to receive an abdominal CT by 3.0-fold (Table 4). One possible explanation might be that patients with traumatic extra-abdominal comorbidities were triaged as more severely injured resulting in a higher use rate of CT. This might also be a reason for the association with lengthened hospital stay, which may be prolonged in these patients.

Table 4

Estimated odds ratios for use of CT vs no CT (additional head and/or thoracic trauma).

	OR	95%-CI	P
Age [years]			
6 to 11	1.49	0.71–3.26	.302
12 to 18	3.34	1.67–7.09	<.001
Male gender	1.57	1.02–2.45	.042
Length of hospital stay	1.01	1.00–1.03	.042
Pediatrics	4.23	2.02–9.36	<.001
General surgery	6.63	3.28–14.37	<.001
Admission to university hospital	2.09	1.09–4.06	.028
Traumatic non-abdominal-comorbidity: head trauma & thoracic trauma*	3.00	1.98–4.58	<.001

* aggregation of ICD-10-GM S00-S09 and/or S20-S29, injuries to the head & injuries to the thorax. CI = confidence interval, ICD-10-GM = International Classification of Diseases in its 10th version, German Modification, OR = odds ratios, reference categories: ≤ 5, Female, Pediatric surgery, non-university hospital.

Table 5

Mean age (overall and within age groups) for patients who underwent abdominal CT.

	Pediatric departments	Non-pediatric departments
Mean age [n (years)]	55 (9.9 ± 4.7)	109 (15.1 ± 3.1)
Mean age within age group		
≤ 5 [n (years)]	12 (3.0 ± 1.4)	2 (4.0 ± ND)
6 to 11 [n (years)]	18 (8.3 ± 1.7)	13 (9.2 ± 1.2)
12 to 18 [n (years)]	25 (14.3 ± 1.4)	94 (16.2 ± 1.5)

CT = computed tomography, ND = not defined; due to low patient numbers and lack of statistical power no further analysis was performed.

4.4. Male teenagers have the highest risk to undergo abdominal CT

The chance for the use of abdominal CT increased with patient age (Table 3). For head trauma the association between cranial CT imaging and patient age in children up to 18 years of age has been demonstrated before.[15] However, it remains unclear why imaging is obtained more frequently with increasing age, especially in teenagers. The possibility to perform cross-sectional imaging in teenagers without sedation may also contribute to this finding. Finally, it has been repeatedly shown that boys sustain injuries more frequent and with higher severity than girls which may contribute to a lower threshold for CT assessment[22]

4.5. University hospitals use CT imaging more frequently

Logistic regression confirmed that admission to a university hospital (vs non-university hospital) was associated with abdominal CT imaging (Tables 3 and 4). This may be explained by a consistent and protocolized approach to trauma care in these centers leaving less room for individual approaches. University hospitals (in Germany) are designated trauma centers with highly standardized treatment protocols in the emergency departments. This corresponds to the finding that designated trauma centers are more likely to perform cranial CT imaging in children with head trauma.[23]

4.6. MRI is more frequently used in pediatric trauma centers

MRI is an excellent imaging technique for diagnosis, evaluation, and characterization of abdominal organ lesions and temporal trauma staging. In our study pediatric departments used MRI in higher frequency than non-pediatric departments (Table 1). One explanation for this finding might be that pediatricians and pediatric surgeons have a higher awareness of the associated increased risk of cancer mortality by CT and performed MRI instead of CT. However, since MRI was only used in 6.5% of all patients further subgroup analysis could not demonstrate significant differences in the use of abdominal MRI between all departments compared to Pediatric Surgery (data not shown).

4.7. Focused Assessment with Sonography for Trauma (FAST) in children with blunt abdominal trauma

The data regarding the efficacy of Focused Assessment with Sonography for Trauma (FAST) examinations for pediatric trauma patients is conflicting.[24,25] However, despite the lack of robust evidence, the use of the FAST examination in pediatric trauma is increasing and patients who undergo FAST have a lesser chance of receiving an abdominal CT scan if clinician suspicion for IAI is low.[26] Since there was no specific OPS code the use of FAST could not be analyzed in this study.

4.8. Centralization of pediatric trauma care is needed

This study included 524 children with blunt abdominal trauma who were treated in 362 different hospitals. Only 24 of these hospitals were designated pediatric trauma centers (data not shown). There is high evidence that injured children and adolescents treated at adult trauma centers have a significant higher in-hospital mortality compared to those treated at pediatric trauma centers.[27–29] Therefore, centralization of pediatric trauma care in Germany is needed.

4.9. Limitations

We are aware of several limitations of our study. Patient data included demographics, diagnosis and procedure codes. The accuracy of coding may have been affected by hospital coding practices. Therefore, it may be possible that our results were influenced by misclassification of imaging outcomes. In addition, claims data are primarily collected for accounting purposes. This leads to missing information for some variables, for example, the severity of the disease. Accordingly, the decision to use cross-sectional imaging could not be entirely reconstructed. Finally, local standards, technical and personnel resources, and the setting in which the primary evaluation took place may have been important confounders influencing the variability of abdominal imaging rates.

5. Conclusion

In this study we demonstrated substantial variation in the use of abdominal CT in the management of children and adolescents with blunt abdominal trauma in Germany. CT was significantly less frequently used in pediatric departments. The substantial variability of the abdominal CT rate among different medical disciplines and centers indicates a potential for reduction of CT imaging by implementation of evidence-based guidelines. Furthermore, our study underlines the need for centralization of pediatric trauma care in Germany not only to improve patient outcome but to avoid radiation-induced cancer mortality (Supplementary Table 2b, http://links.lww.com/MD/F138, Table 5a, http://links.lww.com/MD/F139, and Table 5b, http://links.lww.com/MD/F140).

Author contributions

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