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Untersuchungen zur Prävalenz von Frakturen und Nebenbefunden sowie zur diagnostischen Genauigkeit von Röntgen-Untersuchungen beim älteren Patienten nach einem niederenergetischen Sturz

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Untersuchungen zur Prävalenz von Frakturen und Nebenbefunden sowie zur diagnostischen Genauigkeit von Röntgen-Untersuchungen beim älteren Patienten nach einem niederenergetischen Sturz

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Abkürzungsverzeichnis

cCT	Zerebrale Computertomographie
CT	Computertomographie
EHR	Electronic health record (digitale Patientendaten)
IF	Incidental Finding
IQR	Interquartilsabstand
ISS	Injury Severity Score
KIS	Klinisches Informationssystem
LEF	Low-energy falls
mSV	Millisievert
RIS	Radiological Information System Radiologieinformationssystem
U.S.A.	Vereinigte Staaten von Amerika
XR	X-Ray, Röntgenstrahlung

1. Einleitung

Stürze beim älteren Menschen und deren Folgen gehören zu den häufigsten Ursachen, die zu einer Vorstellung in einer Notaufnahme führen [1]. Die Weltgesundheitsorganisation erklärt Stürze zu der zweithäufigsten Ursache unbeabsichtigter Todesursachen durch Unfall, wobei die Population der über 60-Jährigen die meisten Stürze mit fatalen Folgen erleidet [2]. So liegt die Sturzhäufigkeit bei den 65-Jährigen bei über 30% pro Jahr, bei den über 80-Jährigen mit 50% noch höher [1], was unabhängig von der Sturzursache sowohl aus medizinischer als auch aus Sicht der Patienten ein relevantes Notfallereignis darstellt. US-amerikanischen Daten zufolge erleiden 20 bis 30% der gestürzten älteren Patienten moderate bis schwere Verletzungen wie z.B. Prellungen oder Frakturen [2].

Insbesondere niederenergetische Stürze, sog. Low-Energy Falls (LEFs), d.h. Stürze aus dem Stand, aus dem Bett oder Rollstuhl, einem anderen Möbelstück oder Gegenstand aus einer Höhe von weniger als einem Meter [3], stellen eine der führenden Todesursachen in Industrieländern dar [1, 2].

Sturzauslösende Risikofaktoren sind vielfältig, hierzu zählen z.B. Hochrisikomedikationen, (u.a. Antihypertensiva, Diuretika, Antipsychotika, Beruhigungsmittel und die Kombinationen verschiedener Medikamente), Elektrolytstörungen, Herzrhythmusstörungen, Gangstörungen, eine Visusschwäche oder eine akute systemische Infektion. Einige dieser Risikofaktoren können mit medizinischen Maßnahmen erfolgreich behandelt oder zumindest abgeschwächt werden [4]. Zu den häufigsten sturzbedingten Verletzungen zählen Schädel-Hirn-Verletzungen und Knochenbrüche wie z.B. hüftgelenknahe Frakturen, Beckenverletzungen oder Wirbelkörperfrakturen [2, 5, 6].

Analysen verschiedener nationaler Traumaregister ergeben, dass der LEF der vorherrschende Traumamechanismus in der älteren Population ist und ähnlich schwere Verletzungen verursacht wie hochenergetische Traumamechanismen bei jüngeren Patienten [7]. Das Risiko, einen LEF zu erleiden, steigt mit dem Alter, ebenso die damit verbundene Mortalität und die Morbidität [2, 6]. In Kombination mit der demographischen Entwicklung nimmt folglich die Zahl älterer Patienten, die in einer chirurgischen Notaufnahme vorstellig werden, stetig zu [8]. Ein Großteil der Betroffenen sucht die Notaufnahme selbständig oder in Begleitung eines Rettungsdienstes auf. Nur ein geringer Anteil der gestürzten älteren Patienten wird aufgrund vermuteter oder tatsächlicher schwerer Verletzungen oder aufgrund einer vitalen Kompromittierung nach Voranmeldung über den Schockraum einer Klinik angekündigt und dort behandelt. Aus einer umfassenden retrospektiven bizentrischen Auswertung geht hervor, dass 90% der über 65-Jährigen und Älteren nach einem niederenergetischen Sturz nicht über eine Schockraumaktivierung in der Notaufnahme vorstellig werden [9]. In einer mittelgroßen bis großen Notaufnahme (über 35.000 Patientenkontakte/Jahr) können das 4 bis 8 Patienten pro Tag sein, im Durchschnitt also ca. 3000 Patienten pro Jahr oder mehr. Der überwiegende Anteil der gestürzten älteren Patienten wird somit mit nur geringer Dringlichkeit und vermuteter geringer Verletzungsschwere in der Notaufnahme vorstellig, wie aktuelle große internationale Traumregisterauswertungen zeigen [6, 7].

Die initiale Einschätzung der Verletzungsschwere der Patienten mit LEF ist sowohl präklinisch als auch in der Notaufnahme oft schwierig. Zum einen können die Traumafolgen aufgrund des niederenergetischen Unfallmechanismus unterschätzt werden, zum anderen ist die Sturzanamnese der häufig multimorbid vorerkrankten Patienten erschwert und oftmals wenig präzise. Das erschwert nicht nur die klinische Beurteilung, sondern damit auch die weiterführende diagnostische Abklärung dieser Patienten [10, 11, 12, 13]. Im klinischen Alltag kann dies zu Kontroversen führen: Einerseits besteht die Gefahr der diagnostischen Unterversorgung von häufig übersehenen behandlungsrelevanten Pathologien, andererseits droht eine Überdiagnostik und -behandlung [14].

Neben einer relevanten Prävalenz intrakranieller Traumafolgen und Verletzungen der Halswirbelsäule [15, 16, 17, 18], sind es v.a. Verletzungen des Stammskeletts (Wirbelsäule, Becken), der proximalen Röhrenknochen (Humerus, Femur) sowie Thoraxverletzungen (Rippenserienfrakturen, Hämato-/Pneumothorax), die die ältere Population betreffen. Diese Verletzungen führen zu einer relevanten Morbidität [6, 19], erfordern unter Umständen eine zeitnahe Intervention oder haben, falls initial unerkannt, einen prolongierten Krankenhausaufenthalt mit möglicher verzögerter Versorgung relevanter Verletzungen für die geriatrischen Patienten zur Folge.

In der Notaufnahme werden gemäß der gegenwärtigen klinischen Praxis nach einer ersten ärztlichen Einschätzung und körperlichen Untersuchung der gestürzten Patienten meist CT-Untersuchungen des Kopfes und der Halswirbelsäule durchgeführt, sofern anamnestisch oder klinisch der Verdacht auf ein leichtes oder mittelschweres Schädel-Hirn-Trauma besteht.

Die weitere Diagnostik besteht meist aus einer Serie von Röntgen-Untersuchungen des Stammskeletts und der Extremitäten, um knöcherne Verletzungen in diesen Körperregionen nachzuweisen bzw. auszuschließen. Häufig folgen darauf zusätzliche CT-Untersuchungen der Körperregionen, bei denen das Röntgen keine sichere Frakturdiagnose bzw. deren sicheren Ausschluss nicht zulässt. Dieses sequenzielle Vorgehen ist zeit- und ressourcenintensiv und führt häufig zu einer verzögerten Entlassung (meist nach über 4 Stunden) der Patienten aus der Notaufnahme, bzw. zu einer verspäteten Weiterverlegung auf die entsprechende Station [9]. Untersuchungen haben ergeben, dass die Bildgebung ein unabhängiger Risikofaktor für einen verlängerten Aufenthalt der älteren Patienten in einer Notaufnahme darstellt, was eine relevante Auswirkung auf das Outcome dieser Patienten hat, d.h. prolongierte Aufenthaltszeiten in der Notaufnahme gehen mit einer erhöhten Krankenhausmorbidität und -mortalität einher [20].

Die Mehrschicht-CT gilt als Goldstandard in der modernen Traumadiagnostik. Ihre hohe Sensitivität und Spezifität sowie eine flächendeckende Verfügbarkeit in Industrienationen ermöglicht in der Regel eine akkurate und zeitnahe Diagnosestellung. Insbesondere bei Patienten, die ein Hochrasanztrauma erlitten haben, soll eine Ganzkörper-CT-Untersuchung durchgeführt werden [21]. Für die älteren Patienten mit einem LEF gibt es derzeit noch wenig wissenschaftliche Evidenz, die eine Aussage über eine geeignete Bildgebungsstrategie zulässt [22]. In den aktuellen Leitlinien und klinischen Entscheidungswegen werden Patienten mit einem Alter von über 65 Jahren oder das niederenergetische Trauma nicht explizit berücksichtigt bzw. liegt für geriatrische Patienten keine Validierung vor [21, 23, 24]. Obwohl der niederschwellige Einsatz der CT-Untersuchung bei älteren Patienten mit niederenergetischem Sturz in der Notaufnahme diskutiert wird, ist die Evidenz, die dieses Vorgehen unterstützt, schwach [1, 25]. Nichtsdestotrotz scheint die First-line Ganzkörper-CT-Untersuchung als auch die selektive CT-Untersuchung von einzelnen Körperregionen wie zum Beispiel der Wirbelsäule in der älteren Population mit LEF im klinischen Alltag an Bedeutung zu gewinnen. Die Mehrschicht-CT-Untersuchung zeichnet sich durch einen Mehrwert aus, nicht nur, wenn Röntgen-Befunde inkonklusiv sind bzw. nicht mit dem klinischen Verdacht übereinstimmen, sondern auch aufgrund der raschen und präziseren Diagnostik zum Teil subtiler knöcherner Verletzungen. Die weiterführenden Therapieoptionen bei LEF-Patienten hängen zudem maßgeblich von einer verlässlichen Diagnose der durch den Sturz verursachten Verletzungen bzw. von deren sicherem Ausschluss ab.

Die tägliche klinische Erfahrung zeigt, dass die Röntgendiagnostik von Frakturen des Beckenrings, der Brust- und Lendenwirbelsäule als auch des Thorax ungenau ist. In einer systematischen Literaturanalyse konnten bisher nur wenige retrospektive Beobachtungsstudien identifiziert werden, die die Reliabilität der Röntgen- gegenüber der CT-Untersuchung des Stammskeletts des älteren Patienten nach einem LEF untersucht haben [22]. Berichte über schwerwiegende Gesundheitsfolgen durch verzögerte Diagnosestellungen von ganzen Verletzungsmustern oder übersehene lebensbedrohliche Blutungen im Rahmen von Beckenringfrakturen nach einem LEF erfordern außerdem eine kritische Bewertung [22].

Mit der sog. Niedrigdosis-CT-Untersuchung, bei der die CT-Schnittbildgebung mit reduzierter Strahlendosis durchgeführt wird, lässt sich im Vergleich zur Normaldosis-CT-Untersuchung keine signifikant schlechtere diagnostische Genauigkeit bei der Frakturevaluation nachweisen [26, 27]. Damit steht heutzutage eine Form der Untersuchung zur Verfügung, die hinsichtlich der Strahlenexposition ein günstiges Risiko-Nutzen-Profil aufweist und eingesetzt werden kann. Dem Vorteil der diagnostischen Genauigkeit der CT-Untersuchung im Vergleich zur Röntgen-Untersuchung als initial eingesetzter Bildgebungsmodalität stehen nachteilig auf der anderen Seite die höhere Strahlenexposition durch die CT-Untersuchung und das potentielle Auffinden von Zufallsbefunden gegenüber. Diese können kostenintensive und belastende Folgeuntersuchungen oder -therapien nach sich ziehen. Zufallsbefunde, sog. Incidental Findings (IF) bezeichnen zusätzliche Befunde, die durch die Schnittbildgebung z.B. im Rahmen der Traumadiagnostik zutage treten und nicht mit dem ursprünglichen Unfallereignis assoziiert sind. Einige vorangehende Studien haben die Prävalenz solcher IFs untersucht [28-40]. Der Anteil an Patienten, bei denen mindestens ein Zufallsbefund entdeckt werden konnte, schwankt zwischen 15 und 75,3% [28, 29, 31-34, 36, 37, 41, 42]. Die Studien unterscheiden sich hinsichtlich Ein- und Ausschlusskriterien der Patienten, aber auch u.a. durch den generellen Ausschluss bestimmter Diagnosen, z.B. von degenerativen Gelenkerkrankungen, Sinusitiden, altersbedingen zerebralen Atrophien, bereits abgelaufenen Hirninfarkten oder vaskulären Veränderungen [29, 30, 33, 35]. Ein direkter Vergleich der Studienergebnisse ist somit nur schwer möglich und kann nicht auf die ältere Population mit einem LEF extrapoliert werden.

Die Studien zeigen, dass die Ganzkörper-CT-Untersuchungen mehr IFs nachweisen als CT-Untersuchungen ausgewählter Körperregionen [33]. Die meisten IFs konnten in CT-

Untersuchungen des Abdomens und des Thorax gefunden werden [31, 33, 34, 40, 43], was möglichweise durch die große Anzahl von Organen und Geweben in diesen Körperregionen erklärt werden kann. Zufallsbefunde können in ihrer Akuität zwischen harmlosen Nebenbefunden bis hin zu Diagnosen, die eine dringliche Therapie oder eine Nachsorge- bzw. Kontrolluntersuchung erfordern, variieren. Schwerwiegende Befunde bei Ganzkörper-CT-Untersuchungen, die eine dringliche Behandlung erfordern, werden vor allem intrakraniell, intrathorakal oder intraabdominell gefunden und weisen eine Prävalenz von 4,3 bis 12,5% auf [29-33]. Vorwiegend handelt es sich hierbei um malignomsuspekte Befunde, wie z.B. Lungenrundherde oder Raumforderungen der Bauchspeicheldrüse, der Leber oder des Gehirns, bzw. um Entzündungen z.B. im Rahmen einer Pneumonie [29, 30, 31, 33]. Mehr als die Hälfte der gefundenen IFs sind von geringer klinischer Relevanz bzw. harmlos, [29, 30, 31, 33], z.B. Pleuraplaques [29], Arachnoidalzysten [30, 33] oder eine hämodynamisch nicht relevante Aortensklerose [31].

Die vorangehenden Studien beinhalteten allesamt ein jüngeres Patienten-Kollektiv zwischen 36 und 54 Jahren [29-33, 36-38, 42, 44-46]. Nur zwei der untersuchten Studien [28, 35] wiesen eine Kohorte mit einem Durchschnittsalter von 63 Jahren auf. Die bisherigen Ergebnisse lassen sich damit nur eingeschränkt auf die ältere Population übertragen, zumal das Alter ein unabhängiger Risikofaktor für das Auftreten von IFs zu sein scheint [40]. Das Risiko, in der Bildgebung einen Zufallsbefund zu entdecken, erhöht sich nicht nur in den jeweiligen Altersgruppen, sondern mit jedem einzelnen Lebensjahr [34, 43]. Auch der Schweregrad der gefundenen IFs nimmt mit steigendem Alter zu [31, 32].

Primäre Ziele der im Rahmen der Dissertation durchgeführten Studien waren, den Einsatz der CT-Diagnostik 1. bezüglich des (angenommenen) Vorteils einer im Vergleich zur Röntgen-Diagnostik akkurateren Diagnosestellung bei knöchernen Verletzungen nach einem LEF beim älteren Menschen, 2. bezüglich der Nachteile einer erhöhten Strahlenexposition und 3. bezüglich des Nachweises von Zufallsbefunden mit möglichen Folgeuntersuchungen zu untersuchen. Hierzu wurde die Prävalenz von Frakturen des Achsenskeletts und die diagnostische Genauigkeit von Röntgen-Untersuchungen im Vergleich zu CT-Untersuchungen untersucht.

Als sekundäre Studienziele wurden 4. die kumulative Strahlendosis sowie 5. die Häufigkeit und Relevanz von Zufallsbefunden in den durchgeführten CT-Untersuchungen untersucht.

2. Material und Methoden

2.1. Studiendesign und Studienpopulation

Bei den Studien handelt es sich um eine bizentrische, retrospektive Primäranalyse (Veröffentlichung 1) bzw. eine Sekundäranalyse (Veröffentlichung 2). Hierzu wurden an den Studienstandorten, d.h. am Universitätsspital Basel und am LMU Klinikum München-Großhadern, die jeweils standortspezifischen internen klinischen (SAP-basierte klinische Patientenakte an beiden Studienstandorten) und radiologischen (RIS; LMU: Siemens Syngo Workflow, Basel: SAP-basierte klinische Patientenakten) Datenbanken im Zeitraum von 1. Januar 2016 bis 31. Dezember 2016 nach Patienten von 65 Jahren und älter durchsucht, die innerhalb der ersten 48 Stunden nach Vorstellung in der Notaufnahme eine CT-Untersuchung erhalten hatten. Die elektronischen Patientenakten (EHR) aller so identifizierten Patienten wurden auf das Vorliegen des Sturzmechanismus des niederenergetischen Traumas in Notaufnahmeprotokollen durchsucht.

Ausgeschlossen wurden Patienten, die über den Schockraum vorgestellt wurden oder bei denen bereits auswärts eine Bildgebung durchgeführt wurde. Ebenso wurden Patienten exkludiert, deren Sturzereignis 8 Tage und mehr zurück lag. (Abb. 1a und 1b). Zusätzlich wurden für Veröffentlichung 1 die Patienten ausgeschlossen, die ausschließlich eine Bildgebung der peripheren Knochen (distal des Knies oder Ellbogens) erhielten oder bei denen die CT-Untersuchung einer Körperregion vor der Röntgen-Untersuchung derselben Körperregion stattfand.

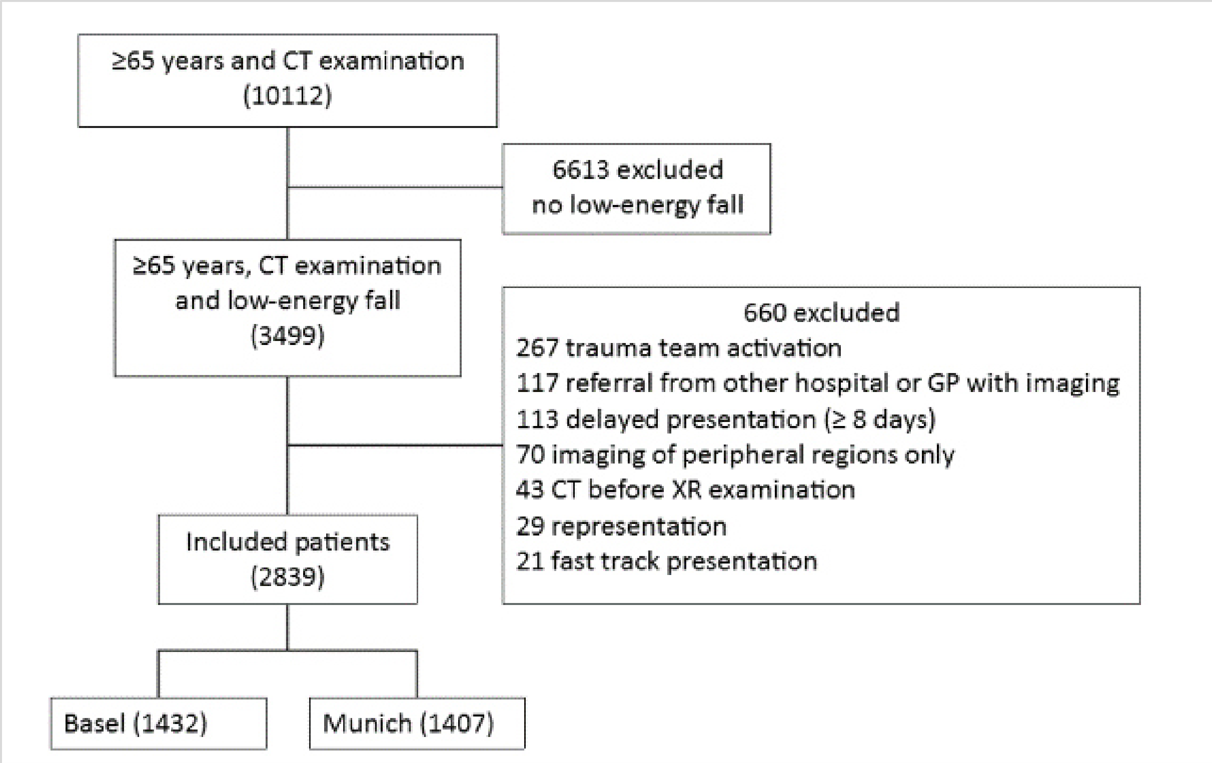

Abb. 1a: Flussdiagramm zu Ein- und Ausschlusskriterien (Veröffentlichung 1)

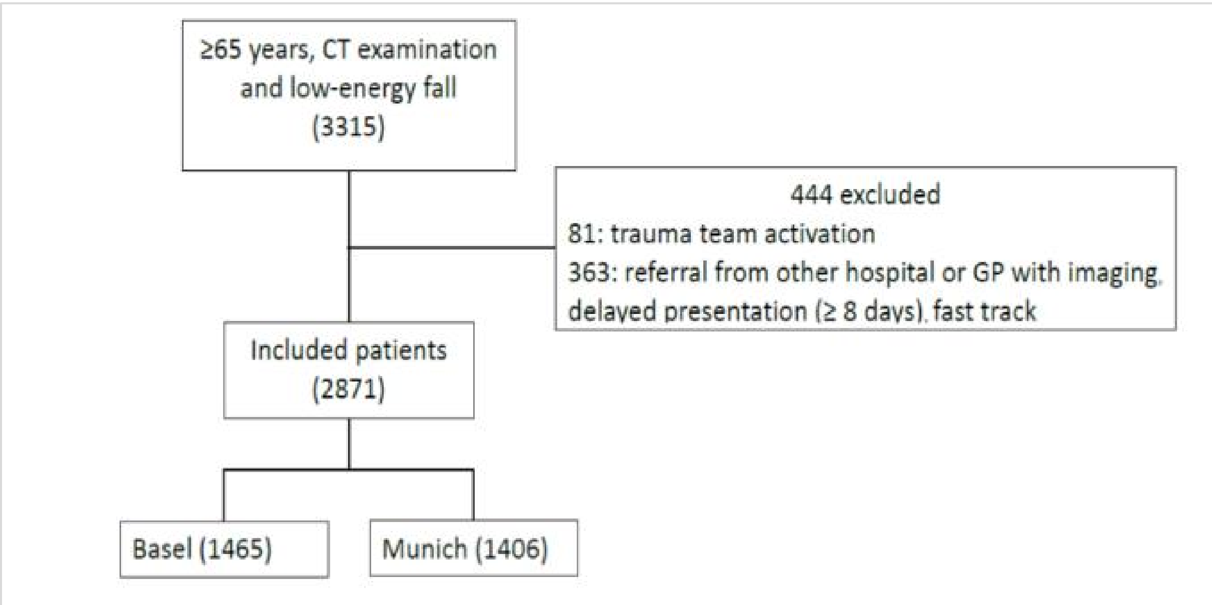

Abb. 1b: Flussdiagramm zu Ein- und Ausschlusskriterien (Veröffentlichung 2).

Für Veröffentlichung 1 wurden basisdemographische Daten, Entlassungsdiagnosen, Anzahl der Frakturen pro Bildgebungsmodalität (anhand des radiologischen Facharztbefundes) von geschulten, nicht verblindeten Untersuchern erfasst und dokumentiert. Die Chart Reviewer wurden hierzu geschult, die erforderlichen Parameter aus den Akten zu lesen und gemäß den Codierungen einzugeben. Die radiologischen Befunde wurden von zwei Untersuchern (1. Klinisches Ausbildungsjahr, Fachärztin) gesichtet, erfasst und verglichen. Bei Unstimmigkeiten oder inkonklusiven Befunden wurden die Befunde erneut diskutiert und bewertet. Weiterhin wurde die kumulative Strahlendosis als Summe der Dosisflächen- (Röntgen) bzw. Dosislängenprodukte (CT) der durchgeführten Einzeluntersuchungen je Patient berechnet.

Für Veröffentlichung 2 wurden die radiologischen Facharztbefunde der CT-Untersuchungen von zwei geschulten, nicht verblindeten Untersuchern unabhängig auf dokumentierte IFs überprüft und einer entsprechenden Kategorie bezüglich des Schweregrades zugeteilt. Empfehlungen im radiologischen Facharztbefund hinsichtlich weiterführender Untersuchungen wurden ebenfalls dokumentiert. Falls vorangegangene CT-Untersuchungen verfügbar waren, wurden diese ebenfalls geprüft, um auszuschließen, dass es sich bei den gefundenen IFs um bereits bekannte Diagnosen handelte. Die doppelte Dateneingabe erfolgte in eine Microsoft Access Datenbank 2010/2016 (Microsoft, Redmond, Washington, USA). Beide Datenbanken wurden schließlich durch einen dritten Untersucher zusammengeführt, der bei Unstimmigkeiten sowohl die CT-Bilder als auch die Befunde erneut prüfte.

Die Studie wurde im Einklang mit den Erklärungen von Helsinki und nach den STROBE-Richtlinien durchgeführt. Eine Genehmigung durch die beiden lokalen Ethikkommissionen wurde eingeholt (EKNZ 2017-01078 genehmigt am 12. Juli 2017, EK LMU 17-217, genehmigt am 10. Mai 2017).

2.1. Statistische Methoden und Auswertung

Für deskriptive Statistiken wurden der Median mit Interquartilsbereich berechnet. Kategoriale Variablen wurden mit dem Pearson Chi-Quadrat- oder dem Fisher-Test verglichen. Die Übereinstimmung zwischen den Beobachtern wurde mithilfe des Kappa-Koeffizienten nach Cohen in einer Teilstichprobe unter Verwendung einer entsprechenden Konfidenz von 95% Intervall (95% KI) ermittelt. Die Auswertung der Daten wurde mit SPSS (SPSS Statistics 26 und RStudio Version 1.4.1.) durchgeführt.

3. Fragestellung und Ergebnisse von Veröffentlichung 1

Primäres Ziel von Veröffentlichung 1 war, die Prävalenz von Frakturen des Stammskeletts (Wirbelsäule, Sternum, Thorax), des Beckenrings und der proximalen langen Röhrenknochen bei Patienten nach LEF zu erheben.

Weiterhin wurde die diagnostische Genauigkeit der Röntgen-Untersuchung mit der CT-Untersuchung als Referenzstandard untersucht und die kumulativen Strahlendosen beider Verfahren berechnet.

Das Durchschnittalter der Patienten betrug 82 Jahre, 64% der Patienten waren weiblich. Die meisten Stürze ereigneten sich aus dem Stand (86,3%), gefolgt von Stürzen von Möbelstücken (9,8%) oder anderen Stürzen aus einer Fallhöhe von weniger als einem 1 Meter bzw. weniger als 5 Treppenstufen (Tab. 1).

Tab. 1: Basischarakteristika (Veröffentlichung 1).

Characteristics	Total (n = 2839)
Age (median, IQR)	82 (71–95)
65–74 (%)	607 (21.4)
75–84 (%)	1133 (44.1)
>85 (%)	1099 (34.5)
Female (%)	1821 (64.1)
In-hospital mortality (%)	62 (3.3)
Hospital admission (%)	1879 (66.2)
Trauma mechanism	
Fall from standing (%)	2451 (86.3)
Fall from low furniture (%)	279 (9.8)
Fall <1 m (%)	109 (3.9)
ISS (median, 95% CI)	3 (2–3)
Non-injurious fall (%)	377 (13.3)

Insgesamt konnten bei 20,6% der untersuchten Patienten knöcherne Verletzungen festgestellt werden. Frakturen des Beckenrings (5,4%), des proximalen Femurs (3,9%), des proximalen Humerus (3,9%) als auch des knöchernen Thorax (3%) hatten die höchste Prävalenz.

Zudem zeigte sich, dass eine von 6 Röntgenuntersuchungen (452/2839) eine weitere CT-Untersuchung der gleichen Körperregion nach sich zog, am häufigsten im Bereich des Beckens (30%), des proximalen Humerus (22%) und der Lendenwirbelsäule (20%) (Abb. 2).

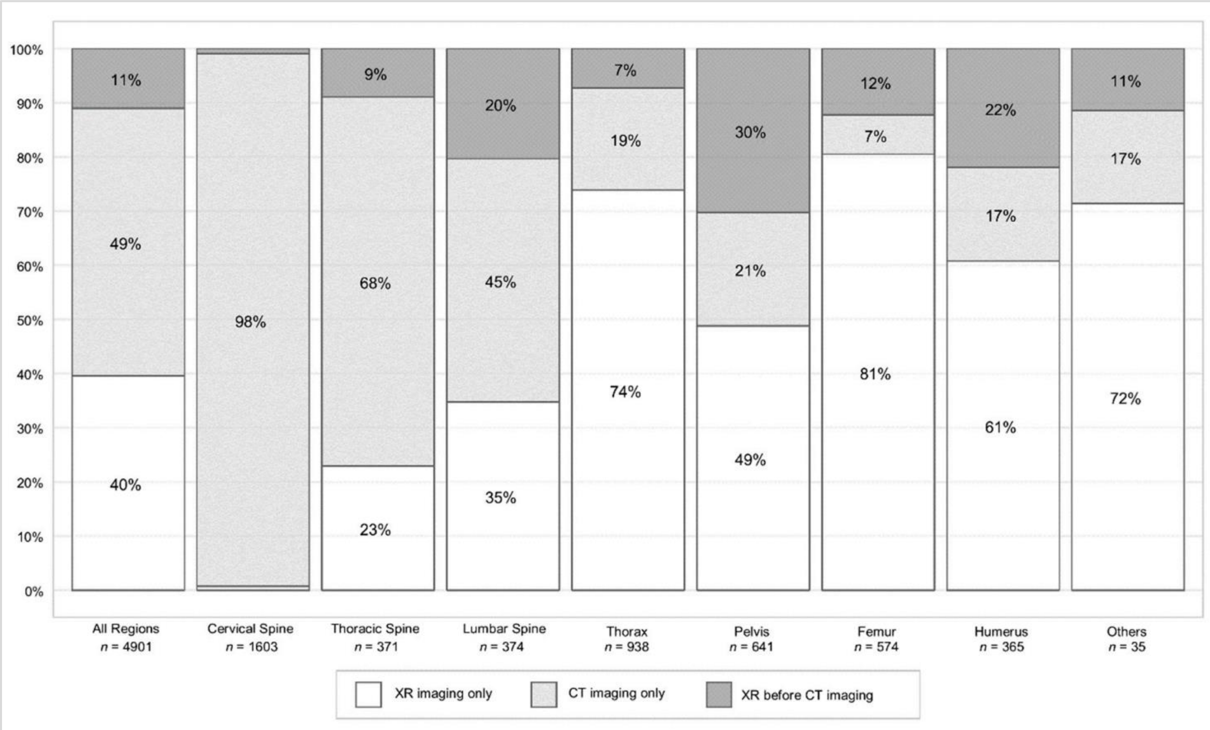

Abb. 2: Anteil (%) der bildgebenden Arbeitsabläufe „XR imaging only", „CT imaging only" und „XR before CT imaging" der einzelnen Körperregionen (Veröffentlichung 1).

Vor allem im Bereich des Beckens (43%), der Brust- und Halswirbelsäule (36% bzw. 33%) und des Thorax (28%) wurden Frakturen im Röntgen nicht erkannt (s. Abb. 3).

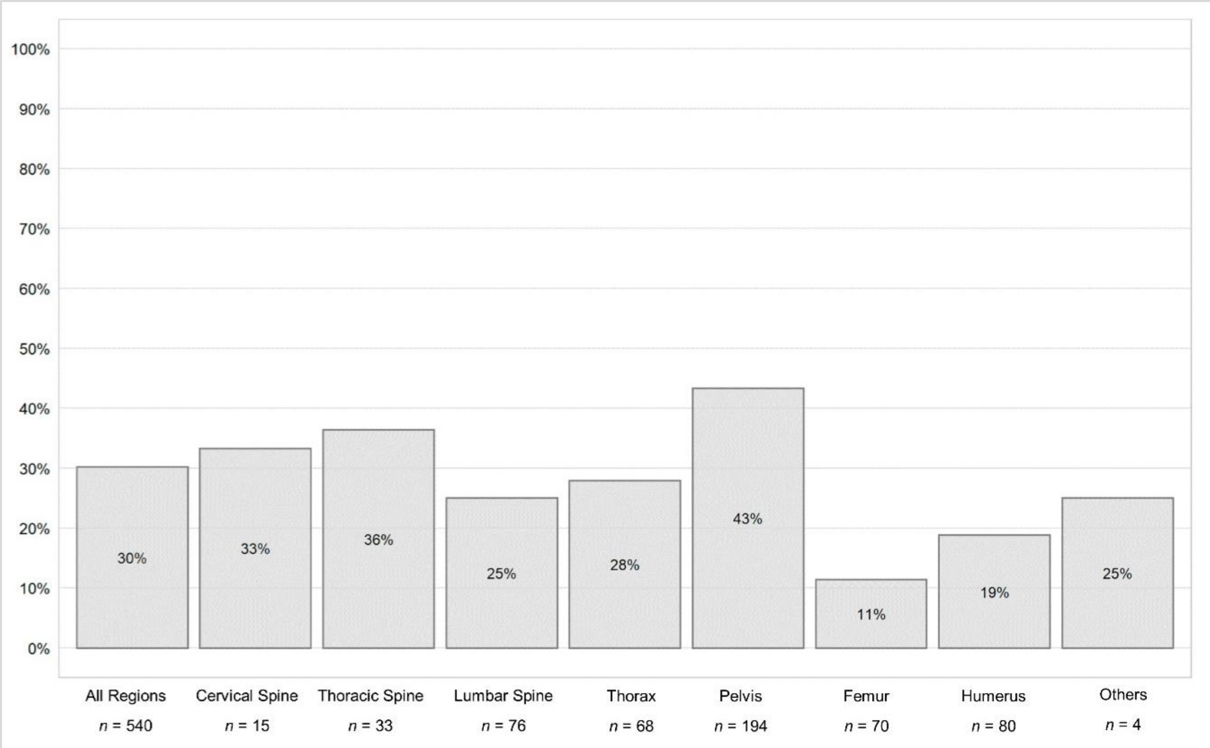

Abb. 3: Kumulativer Prozentsatz der Diagnosen, welche ohne eine nachfolgende CT-Untersuchung übersehen worden wären (Veröffentlichung 1).

Insgesamt zeigte sich für Röntgen-Untersuchungen bezüglich der Erkennung knöcherner Verletzungen eine Sensitivität von 49,7% und eine Spezifität 98,2%. Die Kreuztabellenanalyse zeigte, dass die Frakturerkennung durch Röntgen zwar spezifisch ist, aber eine negative Röntgenuntersuchung Frakturen in der untersuchten Körperregion nicht sicher ausschließen kann (s. Tabelle 2).

Tab. 2: Bestimmung der diagnostischen Genauigkeit (95% KI) der Röntgenuntersuchung zur Frakturerkennung mit CT als Referenzstandard (Veröffentlichung 1).

Region	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR+	LR−	Accuracy (%)
Cervical spine (*n* = 15)	16.7 (0.4–64.1)	100 (66.4–100)	100 (n.a.)	64.3 (55.7–72.0)	n.a.	0.8 (0.6–1.2)	66.7 (38.4–88.2)
Thoracic spine (*n* = 33)	40.0 (19.1–64.0)	100 (75.3–100)	100 (n.a.)	52.0 (43.1–60.8)	n.a.	0.6 (0.4–0.9)	63.6 (45.1–79.6)
Lumbar spine (*n* = 76)	57.8 (42.2–72.3)	100 (88.8–100)	100 (n.a.)	62.0 (53.7–69.7)	n.a.	0.4 (0.3–0.6)	75.0 (63.7–84.2)
Chest (*n* = 68)	22.7 (7.8–45.4)	95.7 (85.2–99.5)	71.4 (34.5–92.2)	72.1 (67.2–76.6)	5.2 (1.1–24.9)	0.8 (0.6–1.0)	72.1 (59.9–82.3)
Pelvis (*n* = 194)	31.4 (23.3–40.5)	98.6 (92.6–99.9)	97.4 (84.2–99.6)	46.5 (43.4–49.5)	22.9 (3.2–163.5)	0.7 (0.6–0.8)	56.7 (49.4–63.8)
Femur (*n* = 70)	82.1 (66.5–92.5)	96.8 (83.3–99.9)	97.0 (82.2–99.6)	81.1 (68.6–89.4)	25.4 (3.7–175.9)	0.2 (0.1–0.4)	88.6 (78.7–94.9)
Humerus (*n* = 80)	75 (62.1–85.3).0	100 (83.2–100)	100 (n.a.)	57.1 (46.2–67.4)	n.a.	0.3 (0.2–0.4)	81.3 (71.0–89.1)
Overall (*n* = 540)	49.7 (44.0–55.3)	98.2 (95.5–99.5)	97.5 (93.7–99.1)	58.0 (55.3–60.7)	27.6 (10.5–74.0)	0.5 (0.5–0.6)	69.8 (65.8–73.7)

PPV = positive predictive value, NPV = negative predictive value, LR+ = positive likelihood ratio, LR− = negative likelihood ratio, n.a. = not applicable, 95% CI = 95% confident interval, XR = plain radiography. *n* refers to the number of “XR before CT imaging” processes in the respective region.

Eine effektive Dosisschätzung wurde in 2484 Fällen (87,5%) durchgeführt. Bei alleiniger CT-Untersuchung betrug die mittlere effektive Dosis 9,14 mSv (Bereich 0,14–46,4 mSv, IQR: 5,94–15,6 mSv). Dieser Wert war signifikant höher als in Fällen mit „Röntgen vor CT-Untersuchung" mit einer mittleren effektiven Dosis von 5,50 mSv (Tab. 3).

Tab. 3: Vergleich der berechneten effektiven Patientendosis (mSV), (Median, IQR)/Pat (n = 2484), (Veröffentlichung 1).

	XR and CT (n = 813)	XR before CT (n = 354)	CT only (n = 218)	cCT only (n = 1,099)	p-value
XR	0.02 (0.00–0.02)	0.06 (0.02–0.33)[a]	n.a.	n.a.	<0.001
CT	3.91 (1.42–4.98)	5.29 (3.17–9.27)[a]	9.14 (5.94–15.6)[b]	4.29 (1.46–5.15)	<0.001
Total	4.02 (1.47–5.12)	5.50 (3.17–9.27)[a]	9.14 (5.94–15.6)[b]	4.29 (1.46–5.15)	<0.001

[a] p<0.001 im Vergleich zu XR und Ct [b] p<0.001 im Vergleich zu XR und CT/XR vor CT/nur cCT. FDR-Korrektur nach Benjamini-Hochberg. N.a. = nicht anwendbar, XR = Röntgen-Untersuchung, XR and CT = XR und CT-Untersuchungen unabhängiger Körperregionen, XR before CT = XR vor CT derselben Körperregion

4. Fragestellung und Ergebnisse von Veröffentlichung 2

Studie 2 untersuchte die Prävalenz von Zufallsbefunden (IFs) in den durchgeführten CT-Untersuchungen der unterschiedlichen Körperregionen, ihre Dringlichkeit bzw. klinische Relevanz, sowie den Zusammenhang von Alter und Geschlecht.

Die Dringlichkeit der gefundenen Zufallsbefunde wurde in 4 Kategorien eingeteilt [31]:

Kategorie 1: IFs, die eine dringliche Untersuchung oder Behandlung erfordern,

Kategorie 2: IFs, die ein Follow-up innerhalb von 3-6 Monaten benötigen,

Kategorie 3: IFs, die gegenwärtig asymptomatisch sind, aber in einem späteren Verlauf klinisch relevant werden,

Kategorie 4: IFs, die harmlos sind und keiner weiteren Intervention oder Untersuchung bedürfen.

Bei 73,9% der untersuchten Patienten wurde mindestens ein Zufallsbefund in einer Körperregion gefunden, insgesamt zeigten sich im Schnitt 1,6 IFs pro Patienten. Die Gruppe der über 85-Jährigen wies dabei die höchste Prävalenz auf. Die höchste Prävalenz von IFs, unabhängig von ihrer Kategorisierung, zeigte sich im Abdomen, gefolgt von Thorax und Schädel (Tab. 4). IFs der Kategorie 3 waren am häufigsten (Tab. 5).

Tab. 4: Prävalenz der IFs gesamt/nach Altersgruppen und pro Untersuchung der unterschiedlichen Körperregionen (Veröffentlichung 2).

Incidental Findings	Patients with An IF (%)
Overall	2122/2871 (73.9)
65 to 74 years	387/616 (62.8%)
75 to 84 years	818/1146 (71.4%)
≥85 years	917/1109 (82.7%)
	Per CT Examination (%)
Head CT (*n* = 2549)	1677/2549 (65.8)
Cervical spine CT (*n* = 1614)	179/1614 (11.1)
Chest CT chest (*n* = 262)	196/262 (74.8)
Abdomen CT (*n* = 149)	116/149 (77.9)
Neck CT (*n* = 1614)	346/1614 (21.4)

Tab. 5: Häufigkeit der Zufallsbefunde pro Kategorie (Veröffentlichung 2).

Category	Definition	%
1	Urgent treatment or further examination	7.6
2	Follow-up within 3 to 6 months	8.8
3	Asymptomatic but potentially relevant	78.5
4	Harmless, no further investigation	5.1

Insgesamt konnten 7,6% der Befunde der Kategorie 1 zugewiesen werden und erforderten eine dringliche Untersuchung oder Behandlung. Sie wurden am häufigsten in der Gruppe der 65- bis 74-Jährigen (Abb. 4) gefunden, vorwiegend im Abdomen oder Thorax (Abb. 5). Zufallsbefunde der Kategorie 2 konnten bei 8,8% der Patienten festgestellt werden, insbesondere im Hals- und Brustbereich. Kategorie 3 Befunde wurden bei 78,5% der Patienten entdeckt, größtenteils bei Untersuchungen des Kopfes und der Wirbelsäule. Kategorie 4 konnten 5,1% aller Befunde zugeordnet werden und fanden sich vorwiegend im Thorax.

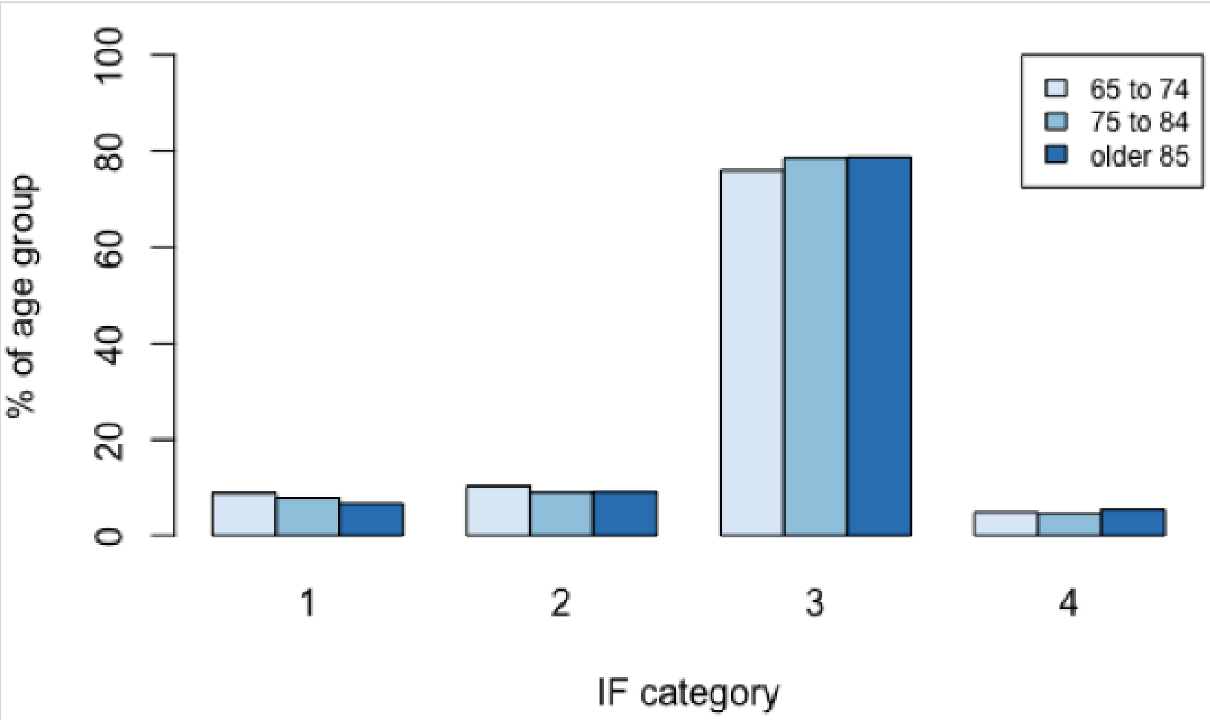

Abb. 4: Verteilung der IFs nach Altersgruppen (Veröffentlichung 2).

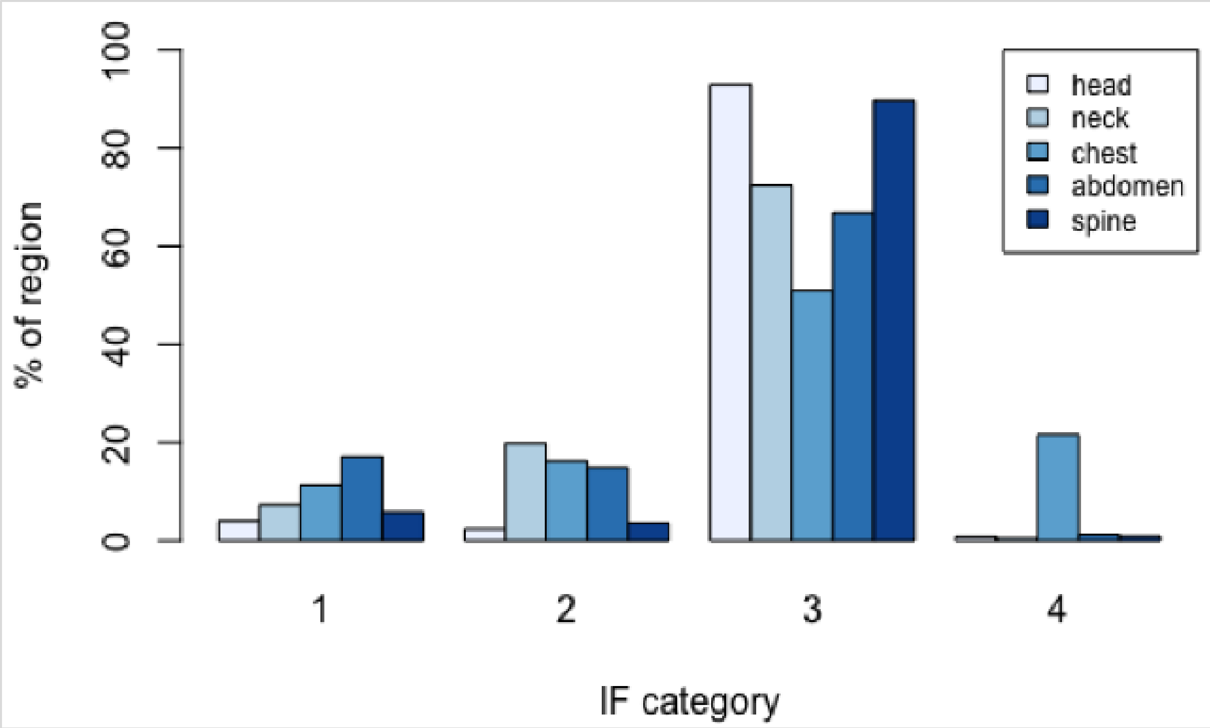

Abb. 5: Verteilung der IF-Schweregrade nach Körperregion (Veröffentlichung 2).

5. Diskussion der wesentlichen Ergebnisse der beiden Studien

Nach Erleiden eines LEF durch einen älteren Menschen wird bei der Vorstellung in der Notaufnahme oftmals die Durchführung einer sofortigen Ganzkörper-CT-Untersuchung vorgeschlagen, jedoch bietet die aktuelle Datenlage keine eindeutige Evidenz zur Abwägung zwischen dem Vorteil einer schnellen und sicheren Frakturdiagnostik und dem Nachteil durch eine erhöhte Strahlenexposition und durch die mögliche Diagnose von Nebenbefunden, die weitere Untersuchungen nach sich ziehen können [14]. Die Ergebnisse der vorliegenden Studien basieren auf einer großen repräsentativen Kohorte und ergänzen weitere Informationen zu der Frage, welche Bildgebungsmodalität bei der Notfalldiagnostik des gestürzten, älteren Patienten in der Notaufnahme genutzt werden kann. Idealerweise sollte die durchgeführte Bildgebung eine schnelle und sichere klinische Entscheidungsfindung ermöglichen.

In der untersuchten Studienkohorte wurde bei jedem fünften Patienten eine knöcherne Verletzung diagnostiziert und jede sechste Röntgen-Untersuchung erforderte eine nachfolgende CT-Untersuchung der gleichen Körperregion. Es konnte gezeigt werden, dass vor allem Frakturen im Bereich des Beckens, der Brust- und Halswirbelsäule und des Thorax im Röntgen initial nicht erkannt wurden. Dies ist dahingehend klinisch relevant, da Beckenring- und Thoraxfrakturen in unserer Kohorte die höchste Prävalenz zeigten. Unsere Ergebnisse bestätigen die Ergebnisse von Heikal et al. [47] und Thomas et al. [48], die eine ähnliche Rate (58% bzw. 55%) von im Röntgen übersehenen Beckenringfrakturen nachwiesen. Die meisten unentdeckten Frakturen fanden sich in diesen Studien im dorsalen Beckenring und Os sacrum, was hinsichtlich der erforderlichen Therapieoptionen und Nachsorge von hoher Relevanz ist [49, 50, 51] und aus diesem Grund eine hohe diagnostische Sicherheit erfordert.

Bezüglich der Diagnostik der HWS-Frakturen ist bemerkenswert, dass jede dritte Fraktur bei alleiniger Röntgen-Untersuchung nicht erkannt worden wäre.

Ebenfalls wurde gezeigt, dass eine unauffällige Röntgen-Untersuchung der Brust- und Lendenwirbelsäule Frakturen dort nicht sicher ausschließen kann. Die aktuellen Leitlinien und klinischen Entscheidungshilfen bezüglich einer Bildgebung und der Wahl der Bildgebungsmodalität bei Wirbelsäulentrauma sind widersprüchlich. So empfiehlt die Eastern

Association for the Surgery of Trauma (EAST) die CT-Untersuchung als Screening-Untersuchung der Wahl, sofern die Bildgebung bei Patienten nach stumpfem Trauma als notwendig erachtet wird [52]. Die aktuellen National Institute for Health and Care Excellence (NICE)-Guidelines hingegen raten zur Röntgen-Diagnostik als First-line Diagnostik für Patienten mit Verdacht auf Verletzungen der thorakalen oder lumbosakralen Wirbelsäule ohne neurologische Defizite [53].

Die Röntgen-Untersuchung des knöchernen Thorax zeigte in unseren Untersuchungen hinsichtlich des Frakturnachweises eine Sensitivität von 22,7%, vergleichbar mit einer aktuellen Untersuchung von Singleton et al [54]. Dort wurden bei ca. 12% der Patienten Frakturen von mehr als drei Rippen, Rippenserienfrakturen und/oder bilaterale Frakturen in der initialen Röntgen-Untersuchung nicht erkannt. Weitere Studien zu stumpfen Traumata bei Patienten jeden Alters haben gezeigt, dass im Thorax-Röntgen Rippenfrakturen und relevante intrathorakale Verletzungen übersehen werden [55, 56, 57]. Dies ist vor allem bezüglich der Tatsache relevant, dass die Mortalität bei älteren Patienten mit stumpfem Trauma mit jeder gebrochenen Rippe um 19% zunimmt [19].

Trotz der nachgewiesenen höheren diagnostischen Genauigkeit sollte die Strahlenbelastung durch die CT-Untersuchung nicht unbeachtet bleiben. Die vorliegende Studie zeigte, dass die höchste effektive Strahlendosis durch die CT-Untersuchungen verursacht wird. Das Lebenszeitkrebsrisiko durch CT-Untersuchungen ist am höchsten für einen CT-Scan des Rumpfes bei Frauen im Alter von 60 bis 69 Jahren mit einer Lebenszeitkrebsinzidenz von 3,6 pro Jahr bei 10.000 Individuen [58]. Dies wird als insgesamt "geringes" Risiko eingeschätzt [59]. Mit weiter zunehmendem Alter verringert sich das Risiko weiter, und stellt folglich in unserer Kohorte mit einem medianen Alter von 82 Jahren klinisch eine eher untergeordnete Rolle bei der Entscheidung für die Bildgebungsmodalität.

Die vorliegenden Daten geben die Basis für eine Nutzen-Risiko-Abwägung, aufgrund derer bei einer CT-Untersuchung die Inkaufnahme einer erhöhten applizierten Strahlendosis in Betracht gezogen werden sollte, sobald der klinische Verdacht auf knöcherne Verletzungen des Rumpfskeletts in einer oder mehreren Regionen besteht, wenn die körperliche Untersuchung nicht schlüssig ist, oder weitere CT-Untersuchungen wie Kopf- und Halswirbelsäulen-CT bei älteren Patienten mit LEF notwendig sind.

Neben einer erhöhten Strahlendosis [60, 61] birgt die CT-Untersuchung die Möglichkeit der Detektion von Zufallsbefunden, die unabhängig sind vom vorangegangenen Trauma und von unterschiedlicher Relevanz sein können [28, 40]. Die vorliegende Studie ist die erste Studie, die CT-Nebenbefunde systematisch an einer älteren Population mit Niederenergietrauma untersucht hat.

Mit insgesamt 73,9% zeigte sich in der hier untersuchten Kohorte eine hohe Prävalenz von Zufallsbefunden, vor allen im Abdomen, im Thorax und im Kopf, wie schon in vorangehenden Studien beschrieben [28, 31, 33, 34, 40, 43]. Die Gruppe der über 85-Jährigen wies dabei, in Übereinstimmung zu früheren Studien [28, 30-32, 34, 36, 38, 39, 42, 46, 62] die höchste Prävalenz auf.

Mehr als 8 von 10 Zufallsbefunden (83,6%) wurden in die Kategorien 3 und 4 und somit als asymptomatisch oder harmlos eingestuft. Die genauere Betrachtung der Befunde zeigte, dass es sich vor allem um degenerative, in erster Linie vaskuläre Veränderungen handelt, wie zum Beispiel Mikroangiopathien, die am ehesten die Durchschnittsprävalenz von altersbedingten Auffälligkeiten in dieser Altersgruppe widerspiegeln.

16,4% der Zufallsbefunde wurden in Kategorie 1 und 2 eingestuft. Somit benötigten weniger als 2 von 10 Patienten eine dringliche Intervention oder ein zeitnahes Follow-Up. Dabei sind drei Aspekte zu berücksichtigen:

1. Zum einen versprechen die häufigsten dieser Diagnosen ein gutes Ansprechen auf die entsprechende Behandlung, beispielsweise Pneumonien (z.B. durch Antibiotikatherapie) oder eine Struma multinodosa (z.B. durch Strumektomie), was sich positiv auf den Krankheitsverlauf der Patienten auswirken kann.
2. Zum anderen stellt der Befund, zum Beispiel eine akute Infektion, eine mögliche behandelbare Sturzursache dar. Dies ist dahingehend relevant, da Infektionen eine häufige Ursache für einen LEF in dieser Altersgruppe sind.
3. Zudem besteht die Möglichkeit, dass diese Zufallsbefunde früher oder später ohnehin klinisch apparent geworden wären und gegebenenfalls mit einem schlechteren Outcome aufgrund der verzögerten Diagnosestellung bzw. des späteren Therapiebeginns einhergehen würden. Trotzdem sollte diese Beobachtung, insbesondere bei den sehr alten Patienten, nicht unkritisch gesehen werden, da ein solcher Zufallsbefund die Lebenszeit möglicherweise nicht zwingend beeinträchtigt.

Wie in einigen Studien beschrieben [29, 30, 31, 33, 35, 36, 37, 40, 46], ist die Dokumentation und Kommunikation der IFs im Hinblick auf den Erstbefund lückenhaft, was möglicherweise auch zu Mehrfachuntersuchungen eines möglicherweise schon vorbekannten Befundes führen kann. Einheitliche Dokumentationsrichtlinien (z.B. strukturierte radiologische Befundung), vor allem in digitalen Patientenakten, können hierbei eine Lösung darstellen und müssen auch in diesem Zusammenhang gefordert werden.

Die medizinisch-ökonomischen Aspekte der vorliegenden Ergebnisse bleiben unklar. Berge et al. [40] berechneten für eine gemischte Patientenkohorte Durchschnittskosten von 2292 Euro pro Zufallsbefund, der eine Intervention nach sich zog, die mittleren Kosten jedes gefundenen IF lag bei 121 Euro [40]. Prospektive Kosten-Nutzen-Analysen liegen derzeit nicht vor, sind aber zu fordern.

Die vorliegenden Studien weisen neben der großen Stärke einer großen repräsentativen und konsekutiven Kohorte auch Limitationen auf. Durch das retrospektive Studiendesign und damit das Fehlen eines systematischen Follow-up der Patienten bleibt die klinische Relevanz der Ergebnisse trotz der großen und repräsentativen Kohorte unklar. Die meisten Patienten in Studie 1 wurden ausschließlich mittels Röntgen-Diagnostik untersucht, was zu einer falsch niedrigen Prävalenz von Frakturen führen kann. Studie 2 analysierte ausnahmslos selektive CT-Scans, womit die Prävalenz nur auf die durchgeführten Untersuchungen der jeweiligen Körperregionen bezogen werden kann. Dies könnte zum einen zu einer Stichprobenverzerrung und zum anderen ebenfalls zu einer Unterschätzung der tatsächlichen Prävalenz der IFs führen. Bekräftigt wird diese Annahme durch eine frühere Studie, die höhere IF-Raten bei Ganzkörper-CT-Untersuchungen im Vergleich zu selektiven CT-Untersuchungen aufweist [33]. Solange digitale Patientenakten nicht allgemein verfügbar sind, sollte in Betracht gezogen werden, dass es sich bei den gefundenen Zufallsbefunden um bereits bekannte Diagnosen handeln könnte, was zu einer falsch hohen Prävalenz führen könnte.

Unsere Ergebnisse unterstützen die Notwendigkeit prospektiver Studien, die die First-line CT-Untersuchung von Kopf-bis-Becken gegen die sequentiellen Röntgen- und CT-Untersuchungen vergleichen, um weitere Erkenntnisse hinsichtlich der Sensitivität der Bildgebungsmodalitäten und der klinischen und prognostischen Relevanz zu erlangen. Die höhere diagnostische Genauigkeit der Frakturerkennung mittels CT scheint naheliegend, dennoch sollten patientenorientierte Endpunkte, wie z.B. die Anzahl der folgenden therapeutischen

Interventionen, die Dauer der Immobilität und die Dauer und Häufigkeit der Hospitalisierung, untersucht werden. Aufgrund der zunehmenden Häufigkeit von LEF-Ereignissen muss unter Berücksichtigung potentieller Vor- und Nachteile einer schnellen und sicheren klinischen Entscheidungsfindung eine klinische Leitlinie bezüglich einer geeigneten Diagnostik für den älteren gestürzten Menschen gefordert werden.

6. Eigenanteil an den vorgelegten Veröffentlichungen

6.1. Eigenanteil Veröffentlichung 1

Der Eigenanteil der Doktorandin an dieser Publikation bestand in der Mitkonzeption der Fragestellungen, des Studiendesigns, des Patienteneinschlusses und der Festlegung der Auswerteparameter. Die Datenerhebung aus den elektronischen Patientenakten erfolgte eigenständig, als eine von insgesamt 5 geschulten Chart-Review Abstractors. Die Doktorandin hat maßgeblich die Auswertung der Studiendaten unterstützt.

6.2. Eigenanteil Veröffentlichung 2

Neben dem wie in der Veröffentlichung 1 genannten wesentlichen Beitrag zum Patienteneinschluss, der Datenerhebung und der eigenständigen Konzeption der Fragestellung, bestand der Eigenanteil der Doktorandin an dieser Publikation weiter in der Festlegung der zu erfassenden Nebenbefunde und der entsprechenden Kategorisierung, der Schulung der weiteren Chart-Review-Abstractors und im Zusammenführen der im Doppel erhobenen Daten mit Abgleich bei diskrepanten Befunden. Die Auswertung und Darstellung der Ergebnisse, Interpretation und wissenschaftliche Einordnung auf Grundlage einer umfassenden Literaturdatenbankrecherche zur Fragestellung wurden eigenständig durch die Doktorandin durchgeführt. Die Erstellung des Manuskriptes erfolgte durch die Doktorandin und wurde mit der Mitbetreuerin und den Ko-Autoren überarbeitet.

7. Zusammenfassung

Die im Rahmen der Dissertation durchgeführten Studien zeigen, dass jeder fünfte Patient über 65 Jahre mit einem LEF eine knöcherne Verletzung am Stammskelett erleidet. Röntgen-Untersuchungen zeichnen sich hierbei lediglich durch eine moderate diagnostische Genauigkeit aus. Die Frakturen mit der höchsten Prävalenz werden dabei am häufigsten übersehen. Die klinische Relevanz dieser Ungenauigkeit für den älteren Menschen ist nicht abschließend geklärt, es muss jedoch unterstellt werden, dass sowohl verspätete Diagnosen mit verlängertem Krankenhausaufenthalt als auch unerkannte Frakturen einen prolongierten Verlauf nach sich ziehen können. Wenngleich Zufallsbefunde in CT-Untersuchungen bei älteren Patienten häufig sind und mit zunehmendem Alter eine höhere Prävalenz aufweisen, zeigt die vorliegende Arbeit, dass mehr als acht von zehn IFs harmlos oder derzeit asymptomatisch sind, und lediglich die häufigsten altersbedingten Grunderkrankungen widerspiegeln. Weniger als zwei von zehn IFs benötigen weitere Untersuchungen.

Die Ergebnisse der vorliegenden Studien deuten darauf hin, dass die Nachteile der höheren Strahlenbelastung und der hohe Anteil von Zufallsbefunden durch CT-Untersuchungen in der initialen (first line) Bildgebung zu Gunsten einer akkuraten und schnellen Frakturdiagnostik vernachlässigt werden können.

8. Summary

Our study demonstrates that one of five patients of 65 years or older with a LEF suffer from traumatic osseous lesions while plain radiography is characterized by a moderate diagnostic accuracy. The recent data depict, that fractures with the highest prevalence have the highest failure rate in regard of fracture detection, entailing potential serious health consequences, particularly in the elderly population. Although IFs in CT scans are common in elderly patients and demonstrate increasing prevalence with increasing age, it should be noted that more than eight out of ten IFs are harmless or currently asymptomatic, reflecting the most common underlying age-related diseases, whereas less than two in ten require further investigations. Considering our results, disadvantages of higher radiation exposure and the frequent occurrence of IFs in CT examinations in first-line imaging might be disregarded in favor of accurate and rapid fracture diagnosis.

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Anhang A: Veröffentlichung 1

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Article

Prevalence of Fractures and Diagnostic Accuracy of Emergency X-ray in Older Adults Sustaining a Low-Energy Fall: A Retrospective Study

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Abstract: Background: Plain radiography (XR) series are standard of care for detection of fall-related fractures in older patients with low-energy falls (LEF) in the emergency department (ED). We have investigated the prevalence of fractures and diagnostic accuracy of XR imaging in the ED. Methods: 2839 patients with LEF, who were presented to two urban level I trauma centers in 2016 and received XR and computed tomography (CT), were consecutively included in this retrospective cohort study. The primary endpoint was the prevalence of fractures of the vertebral column, rib cage, pelvic ring, and proximal long bones. Secondary endpoints were diagnostic accuracy of XR for fracture detection with CT as reference standard and cumulative radiation doses applied. Results: Median age was 82 years (range 65–105) with 64.1% female patients. Results revealed that 585/2839 (20.6%) patients sustained fractures and 452/2839 (15.9%) patients received subsequent XR and CT examinations of single body regions. Cross-tabulation analysis revealed sensitivity of XR of 49.7%, a positive likelihood ratio of 27.6, and negative likelihood ratio of 0.5. Conclusions: XR is of moderate diagnostic accuracy for ruling-out fractures of the spine, pelvic ring, and rib cage in older patients with LEF. Prospective validations are required to investigate the overall risk–benefit of direct CT imaging strategies, considering the trade-off between diagnostic safety, health care costs, and radiation exposure.

Keywords: low-energy fall; older adult; computed tomography; fracture; X-ray

1. Introduction

Low-energy falls (LEF) occur in one-third of adults over the age of 65 each year, and are a leading cause of death in developed nations [1]. The emergency department (ED) visit rates for LEF among older adults are increasing [2]. In the United States of America 20%–30% of older people who have fallen suffer moderate to severe injuries, such as bruises, hip fractures or head trauma [3]. LEF are associated with significant morbidity and mortality that appear to increase with age [3,4]. Trauma registry analysis emphasizes that LEF are the predominant trauma mechanism of older individuals leading to injury severities similar to high-energy mechanisms in younger patients [5].

Assessment and diagnostic evaluation of these patients are difficult, and they are jeopardized by a systemic underestimation of the trauma mechanism, resulting in potentially severe or even life-threatening injuries and often complicated medical or neurological conditions [6–9].

The majority of older adults suffering from LEF presented themselves to the ED as walk-in patients or with emergency medical services without previous trauma-team activation. Diagnosis of skeletal injuries is predominantly performed by plain radiography (XR). However, XR might miss a substantial portion of fractures of the rib cage and pelvic ring [10–13]. Evaluation of the vertebral column after LEF is frequently limited to computed tomography (CT) of the cervical spine [14]. Supplementary imaging of the thoracolumbar spine often depends on clinical presentation and clinical experience of the treating physician. Moreover, history and physical examination findings are generally inaccurate to rule-in or rule-out fractures of the thoracolumbar spine [15], and the current guidelines [16,17] cannot be readily applied to older adults with LEF.

The objectives of this study were to analyze the prevalence of fractures of the axial skeleton (vertebral column, sternum, rib cage), the pelvic ring, and the proximal long bones, and to measure the diagnostic accuracy of XR and the cumulative radiation doses applied to older adults after LEF with radiological imaging.

2. Materials and Methods

2.1. Study Design and Setting

This bicentric, binational retrospective study was carried out in two university tertiary care hospitals in Switzerland (University Hospital Basel) and Germany (University Hospital of Ludwig Maximilian University Munich) using electronic health records (EHR). The study is in accordance with the Declaration of Helsinki and was conducted using STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. Ethics approval was obtained from local ethics committees (EKNZ 2017-01078, EK LMU 17-217).

2.2. Study Population

The study population includes individuals ≥65 years of age who presented to one of the two EDs from 1 January 2016 to 31 December 2016 and received a CT examination of the axial skeleton, pelvic ring or proximal long bones within 48 h of the index visit. All the individuals suffered from a documented LEF, including fall from standing height (W00, W01, W03, W04, and W18), fall out of bed/from chair/wheel-chair or other low level furniture (W05–W08) or fall from low level (W10, if ≤1 m) (according to International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) [18]) in the last 7 days before ED presentation.

Exclusion criteria were: initial presentation via resuscitation room, referral from general practitioners or other hospitals with preceding imaging, presentation via fast track process, delayed presentation (≥8 days after the fall), re-presentation due to the same incident, CT examinations solely distal from knee or elbow, and XR examination following diagnostic CT examination.

2.3. Data Collection

Radiology information systems (RISs) in both study centers were screened for patients aged 65 and older receiving a CT examination within 48 h of their index visit. EHR of all retrieved cases were manually screened for documented LEF. Baseline demographics, final injury diagnosis (from the final discharge report), number of fractures per imaging modality (from the final board certified radiologist's report), number, and modality of XR and CT studies were extracted from the EHR by two trained observers (A.L., I.A., N.M., and V.P.). Disagreements or equivocalness was decided upon by a third observer (A.L. and V.P.) uninvolved in the initial extraction. Screening and chart review abstraction were conducted in accordance with the recommendations for medical chart review [19,20], which were fulfilled for 11 of 12 guidelines (abstractors were not blinded to the hypothesis). Interrater agreement for inclusion criteria was determined using corresponding 95% confidence interval. Double data entry was performed in a Microsoft Access 2010/2016 database (Microsoft, Redmond, Washington, DC, USA).

Detailed description of calculation of injury severity score (ISS) and estimation of cumulative radiation doses are provided in the online-only Supplementary Methods.

2.4. Key Outcome Measures

The primary endpoint of the study was to assess the prevalence of fractures in older patients with LEF. Secondary endpoints were the measurements of diagnostic accuracy of XR and cumulative radiation doses. Measures of diagnostic accuracy were: sensitivity and specificity, positive (PPV) and negative predictive values (NPV), positive (LR^+) and negative likelihood-ratios (LR^-), and the accuracy (diagnostic effectiveness) with CT set as a reference standard [21]. Prevalence of missed fractures in XR of the axial skeleton, pelvic ring, humerus, femur, and others (clavicle, scapula), and performance of CT examination following XR examination of the same body region were assessed.

2.5. Statistics

For descriptive statistics, arithmetic means or medians with ranges or interquartile ranges (IQR) were used as appropriate. For comparisons in categorical values, Pearson's Chi-squared test and Fisher's exact test were used; for comparisons in scaled or normally distributed values, the *t*-test or false discovery rate (FDR) correction according to Benjamini-Hochberg was performed as appropriate. A binary logistic regression model was calculated to identify risk factors (age class, gender, disposition, in-hospital mortality, trauma mechanism, ISS, and study center) for performance of CT examination after XR examination of the same body region. A p-value <0.05 was considered significant. Statistical analyses were performed using SPSS Statistics 22 and R version 3.5.2.

3. Results

3.1. Baseline Data

We identified 10,112 cases that presented to the ED of the two study centers between January 2016 and December 2016 and received a CT examination. In 3499 (34.6%) cases, LEF were related to the index presentation. Finally, 2839 cases were included in both centers (Figure 1) with a median age of 82 (range 65–105), of which 1821 (64.1%) were female (Table 1). Detailed characteristics and between centers comparisons are reported in the online-only Supplementary Results. Interrater agreement for patient inclusion was 94.3% (95% CI: 93.1–95.5).

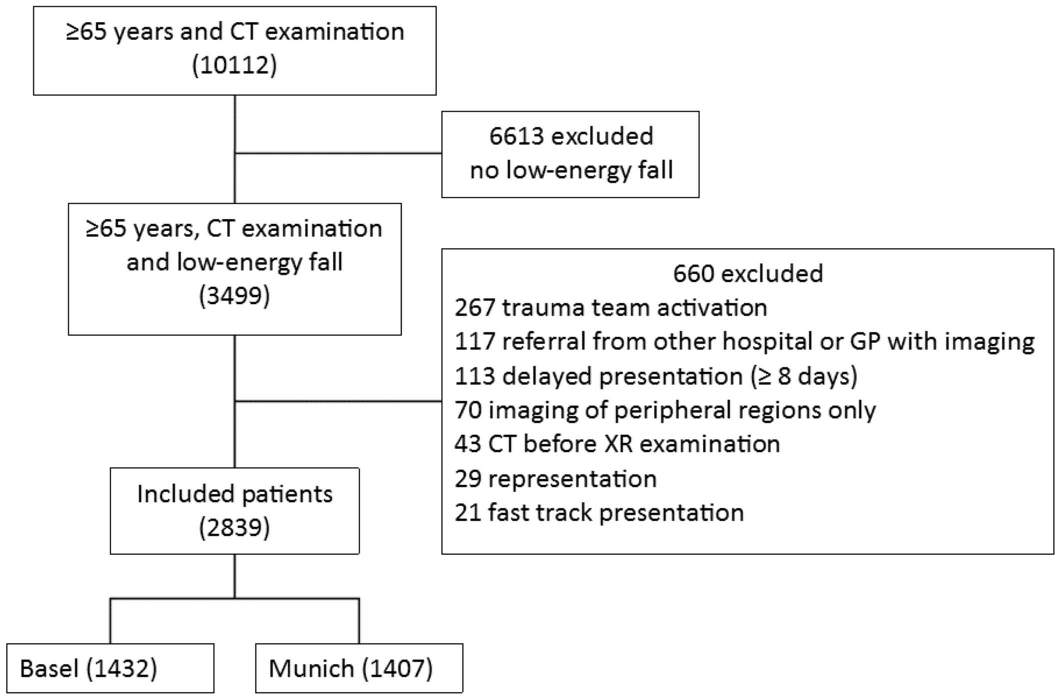

Figure 1. Inclusion and exclusion flow diagram of patient selection from 1 January 2016 to 31 December 2016 in Basel and Munich, receiving computed tomography (CT) examination of the head, spine, chest, pelvic ring or proximal long bones during emergency department (ED) presentation or within 48 h. GP = general practitioner, XR = plain radiography.

Table 1. Baseline characteristics of 2839 older adult patients presenting with low-energy falls from 1 January 2016 to 31 December 2016 and characteristics of patients (n = 452) that received "XR before CT imaging".

Characteristics	Total (n = 2839)	Basel (n = 1432)	Munich (n = 1407)	Patients with XR before CT (n = 452)
Age (median, IQR)	82 (71–95)	82 (71–95)	81 (80–94)	83 (82–84) [b]
65–74 (%)	607 (21.4)	310 (21.6)	297 (21.1)	84 (18.6) *
75–84 (%)	1133 (44.1)	541 (42.9)	592 (45.4)	166 (36.7)
>85 (%)	1099 (34.5)	581 (35.5)	518 (33.5)	202 (44.7)
Female (%)	1821 (64.1)	915 (63.9)	906 (64.4)	342 (75.7) ***
In-hospital mortality (%)	62 (3.3)	26 (2.8)	36 (3.7)	13 (2.9)
Hospital admission (%)	1879 (66.2)	916 (64)	963 (68.4) [a]	391 (86.5) ***
Trauma mechanism				
Fall from standing (%)	2451 (86.3)	1233 (86.1)	1218 (86.6)	397 (87.8) **
Fall from low furniture (%)	279 (9.8)	144 (10.1)	135 (9.6)	33 (7.3)
Fall <1 m (%)	109 (3.9)	55 (3.8)	54 (3.8)	22 (4.9)
ISS (median, 95% CI)	3 (2–3)	3 (3–4)	3 (3–4)	5 (5–5) [b]
Non-injurious fall (%)	377 (13.3)	194 (13.5)	183 (13.0)	28 (6.2)

If not otherwise stated, data are reported as number of patients (%). ISS = injury severity score; IQR = interquartile range. Non-injurious fall: ISS = 0. [a] $p < 0.05$ between centers (Fisher's exact test); * $p < 0.05$/** $p < 0.001$ between patients with XR before CT and patients with XR or CT only (Pearson Chi-squared test); *** $p < 0.001$ between patients with XR before CT and patients with XR or CT only (Fisher's exact test); [b] $p < 0.05$ between patients with XR before CT and patients with XR or CT only (t-test).

3.2. Imaging Patterns

Three patterns of imaging were identified for each investigated body region: (1) "XR examination only"; (2) "CT examination only"; and (3) "XR before CT examination". In 452/2839 (16%) patients "XR before CT examination" was performed in at least one of the body regions of interest, while 464/2839 (16.3%) patients received solely head CT. The remaining 1923/2839 (67.7%) patients received XR or CT or both examinations in different body regions of interest.

Results of regression analysis are shown in Table 2. For performing "XR examination only" or "CT examination only" of a respective body, patients from 65 to 74 years of age had significantly increased odds. Female patients were more likely to receive "XR before CT examination". Patients with a fall from standing position had significantly increased odds of CT examination following XR examination of a distinct body region. Patients discharged from the ED were more likely to have received "XR examination only" or "CT examination only".

Table 2. Binary logistic regression of performing XR or CT separate or XR before CT examination.

Imaging Patterns		XR or CT			XR before CT		
Variable	**Level**	**OR**	**95% CI**	***p*-Value**	**OR**	**95% CI**	***p*-Value**
Age (years)	65–74	119.2	51.3–277.4	<0.001	0.01	0.004–0.2	<0.001
	75–84	1.1	0.4–3.1	0.9	0.9	0.3–2.7	0.9
	≥85	Ref			Ref		
Gender	Female	0.5	0.4–0.8	0.001	1.9	1.3–2.8	0.001
	Male	Ref			Ref		
Trauma mechanism	Fall from standing	0.001	0.0–0.002	<0.001	1053.4	427.0–2599.0	<0.001
	Fall from low furniture	0.7	0.2–2.1	0.5	1.5	0.5–4.9	0.5
	Fall <1 m	Ref			Ref		
Disposition	discharge	3.5	2.3–5.5	<0.001	0.3	0.2–0.4	<0.001
	admission	Ref			Ref		
Mortality	In-hospital	0.8	0.3–2.4	0.7	1.2	0.4–3.6	0.7
	survived	Ref			Ref		
ISS	<10	1.5	0.7–3.4	0.3	0.6	0.3–1.5	0.3
	10–15	1.2	0.5–3.3	0.7	0.8	0.3–2.2	0.7
	>15	Ref			Ref		
Center	Basel	0.8	0.6–1.2	0.2	1.2	0.9–1.8	0.2
	Munich	Ref			Ref		

CT = computed tomography, ISS = injury severity score, OR = odds ratio, XR = plain radiography, 95% CI = 95% confidence interval.

Altogether, 4901 single imaging procedures (in 2375/2839 cases) of either identified pattern were found. Of 4901 procedures, 540 (11%) were identified as "XR before CT examination" (Figure 2). The highest incidences for sequentially imaging were observed in the pelvic ring with 194/641 (30%), the proximal humerus with 80/365 (22%), and the lumbar spine with 76/374 (20%) of the examinations (Figure 2). The cervical spine was imaged by "CT examination only" in 1577/1603 (98%) examinations. Center specific imaging approaches are reported in Table S1.

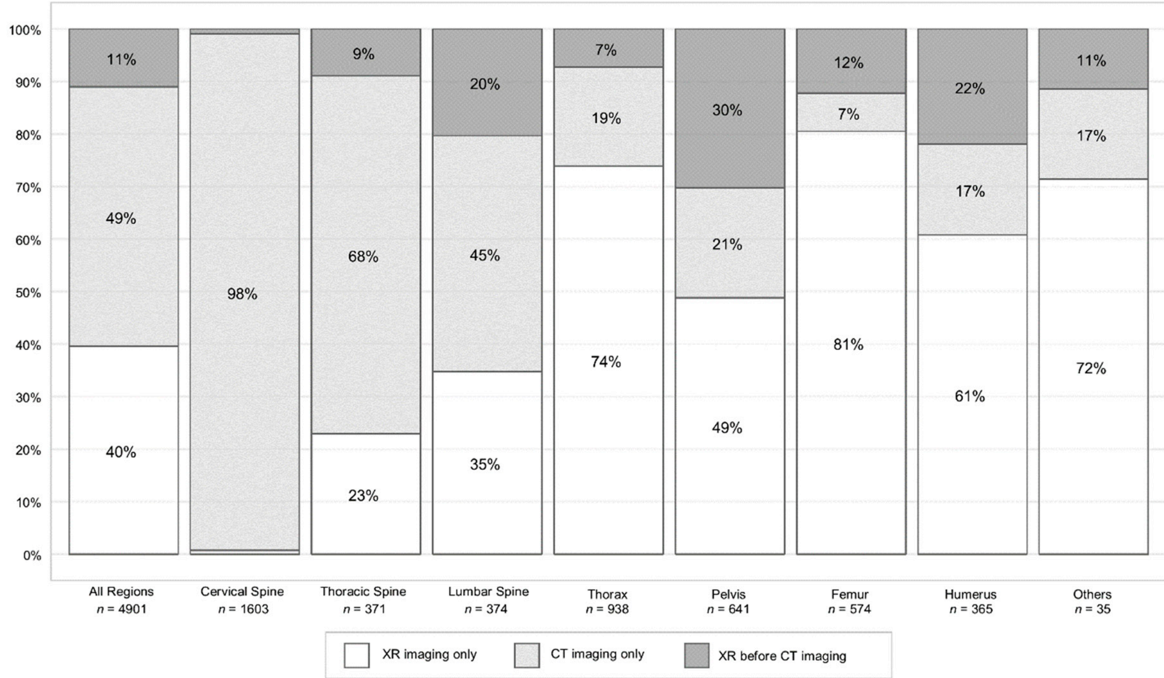

Figure 2. Proportion (%) of imaging work-flows "XR imaging only", "CT imaging only", and "XR before CT imaging" (*n* = 4901 imaging processes) of the cervical spine, thoracic spine, lumbar spine, rib cage, pelvic ring, proximal femur and humerus, and other regions (clavicle, scapula, sternum, and coccyx). CT = computed tomography, XR = plain radiography.

3.3. Prevalence of Fractures and Diagnostic Accuracy Measurements

Fractures were detected in 585/2839 (20.6%) patients in the investigated skeletal regions by XR, CT or both. Fracture prevalence was calculated as follows: cervical spine 39/2839 (1.4%), thoracic spine 62/2839 (2.2%), lumbar spine 71/2839 (2.5%), rib cage 86/2839 (3.0%), pelvic ring 152/2839 (5.4%), humerus 112/2839 (3.9%), femur 112/2839 (3.9%), and others 18/2839 (0.6%).

Cross-tabulation was performed for 540 "XR before CT examination" procedures. Measurements of diagnostic accuracy of XR to detect fractures with CT set as reference standard were calculated for the different body regions (Table 3). Overall, sensitivity of XR to detect fractures was 49.7% (95% CI: 44.0–55.3) and specificity was 98.2% (95% CI: 95.5–99.5). The PPV was 97.5% (95% CI: 93.7–99.1), NPV was 58.0% (95% CI: 55.3–60.7), LR^+ was 27.6 (95% CI: 10.5–74.0), and LR^- was 0.5 (95% CI: 0.5–0.6) (Table 3). Figure 3 illustrates the cumulative percentage of diagnosis that would have been inaccurate if CT had not been performed. A detailed summary of false positive, false negative, true negative, and true positive diagnosis of XR are reported in Table S2.

Table 3. Summary of measurements of diagnostic accuracy (95% CI) of XR for fracture detection according to computed tomography as reference standard.

Region	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR^+	LR^-	Accuracy (%)
Cervical spine (*n* = 15)	16.7 (0.4–64.1)	100 (66.4–100)	100 (n.a.)	64.3 (55.7–72.0)	n.a.	0.8 (0.6–1.2)	66.7 (38.4–88.2)
Thoracic spine (*n* = 33)	40.0 (19.1–64.0)	100 (75.3–100)	100 (n.a.)	52.0 (43.1–60.8)	n.a.	0.6 (0.4–0.9)	63.6 (45.1–79.6)
Lumbar spine (*n* = 76)	57.8 (42.2–72.3)	100 (88.8–100)	100 (n.a.)	62.0 (53.7–69.7)	n.a.	0.4 (0.3–0.6)	75.0 (63.7–84.2)
Chest (*n* = 68)	22.7 (7.8–45.4)	95.7 (85.2–99.5)	71.4 (34.5–92.2)	72.1 (67.2–76.6)	5.2 (1.1–24.9)	0.8 (0.6–1.0)	72.1 (59.9–82.3)
Pelvis (*n* = 194)	31.4 (23.3–40.5)	98.6 (92.6–99.9)	97.4 (84.2–99.6)	46.5 (43.4–49.5)	22.9 (3.2–163.5)	0.7 (0.6–0.8)	56.7 (49.4–63.8)
Femur (*n* = 70)	82.1 (66.5–92.5)	96.8 (83.3–99.9)	97.0 (82.2–99.6)	81.1 (68.6–89.4)	25.4 (3.7–175.9)	0.2 (0.1–0.4)	88.6 (78.7–94.9)
Humerus (*n* = 80)	75 (62.1–85.3).0	100 (83.2–100)	100 (n.a.)	57.1 (46.2–67.4)	n.a.	0.3 (0.2–0.4)	81.3 (71.0–89.1)
Overall (*n* = 540)	49.7 (44.0–55.3)	98.2 (95.5–99.5)	97.5 (93.7–99.1)	58.0 (55.3–60.7)	27.6 (10.5–74.0)	0.5 (0.5–0.6)	69.8 (65.8–73.7)

PPV = positive predictive value, NPV = negative predictive value, LR^+ = positive likelihood ratio, LR^- = negative likelihood ratio, n.a. = not applicable, 95% CI = 95% confident interval, XR = plain radiography. *n* refers to the number of "XR before CT imaging" processes in the respective region.

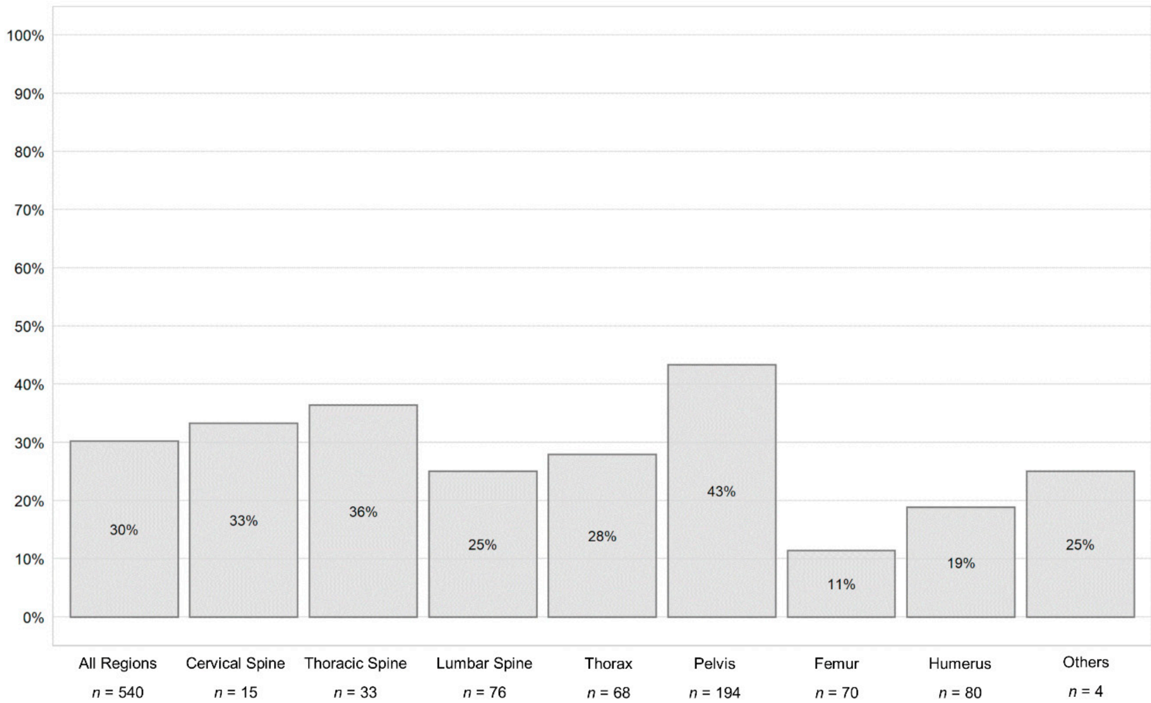

Figure 3. Cumulative percentage of diagnosis that would have been inaccurate if CT had not been performed in "XR before CT examination" (*n* = 540 imaging processes) of the cervical spine, thoracic spine, lumbar spine, rib cage, pelvic ring, proximal femur and humerus, and other regions (clavicle, scapula, sternum, and coccyx).

3.4. *Effective Dose Estimation*

Effective dose estimations were accomplished in 2484 cases (87.5%). The highest effective doses of median 9.14 mSv (range 0.14–46.4 mSv, IQR: 5.94–15.6 mSv) were administered in cases with "CT examination only”. This was significantly higher than in cases with “XR before CT examination” with a median effective dose of 5.50 mSv (range 0.03–49.6 mSv, IQR: 3.17–9.27; $p < 0.001$ post-hoc FDR according to Benjamini–Hochberg). Detailed dose estimations in the investigated skeletal regions and comparison to previously published data are reported in Tables S3 and S4.

4. Discussion

Low-energy falls of older adults are associated with significant morbidity and mortality [3,4] despite the low-impact trauma mechanism. Since clinical assessment and diagnostic evaluation of these patients are difficult, the systemic underestimation of their fall-related, potentially life threatening injuries exposes them to the risk of undiagnosed injuries or unfavorable outcomes [6–9].

Standard of care diagnosis of skeletal injuries relies on plain XR, although XR might miss a substantial portion of fractures of the rib cage and pelvic ring [10–13]. Evaluation of the vertebral column is frequently limited to imaging of the cervical spine [14], whereas supplementary imaging of the thoracolumbar spine often depends on clinical presentation and clinical experience of the treating physician, which might be submitted to diagnostic inaccuracy [15].

The main result of this study, representing a subset of a large patient cohort recently published [22], is that one out of five older adults with LEF, recorded at the ED, has suffered from fractures of the axial skeleton, pelvic ring or proximal long bones, as diagnosed by XR and CT examinations. Fractures of the pelvic ring, proximal femur, and humerus show the highest prevalence in this cohort.

Overall, our observation demonstrates that in one out of five XR examinations, sequel CT examinations of the same body region were requested for diagnostic assertion. For sequel examinations cross-tabulation analysis demonstrated that fracture detection by XR is on the one hand specific, but, on the other hand, a negative XR does not safely rule-out fractures in the investigated body region. In our study, XR showed the lowest diagnostic accuracy for fracture detection in the pelvic ring, cervical and thoracic spine, and rib cage.

The prevalence of 5.4% for pelvic ring fractures in our cohort is slightly lower than the previously described 7.2% in a large trauma registry analysis [23]. This might be explained by a potential preselection of more severely injured LEF patients, who are eligible for trauma registry inclusion. We found that 43% of XR examinations followed by CT examination missed one or more fractures of the pelvic ring. Therefore, we suspect the real prevalence for pelvic ring fractures to be higher in our cohort. The specificity of XR for fracture diagnosis was 98.6% and the LR^+ was 22.4, suggesting that patients with an XR-detected fracture of the pelvic ring did indeed have a pelvic ring fracture. On the other side, a LR^- of 0.6 indicates that a negative XR does not safely rule-out a fracture of the pelvic ring. These findings are confirmed by few other studies on the targeted population. Heikal et al. found 58% of hip and pelvic ring fractures were missed in XR [11]. Thomas et al. showed that from 199 negative XR of the pelvic ring, 55% of the fractures of the pelvic ring and the proximal femur were missed [13]. Another study with consecutive imaging of the pelvic ring yielded a LR^- of 0.89 and 0.27 for detection of sacral fractures and pubic bone fractures, respectively [12]. In these studies, the majority of undetected fractures were located in the dorsal pelvic ring and sacrum. This defines fragility fractures of the pelvis Type II to IV [24], which might require surgical therapy when unstable or provoke prolonged, pain-induced immobilization of the patient [24–26]; this, in our opinion, demands diagnostic assurance.

Rib fractures were XR and CT detected in 3.0% of the patients in our cohort. Of these cases with rib fractures, nearly 12% had fractures of more than three ribs, serial and/or bilateral, which were not detected by X-ray. The prevalence was remarkably higher—by 29%—in a recent study, when only patients with LEF and suspected injuries of the rib cage were included for radiological examinations [10]. Furthermore, in our analysis the measurements of diagnostic accuracy for chest XR to detect rib fractures revealed low sensitivity (22.7%) and likelihood ratios (LR^+ 5.3, LR^- 0.8), demonstrating that application of chest XR examination does not safely rule-in or rule-out fractures of the rib cage. This observation is confirmed by the retrospective cohort study of Singleton et al. on 330 non-consecutive older patients with LEF and trauma room presentation, where chest CT followed chest XR [10]. They showed a sensitivity of 42% of chest XR and a LR^{-} of 0.6 of XR to rule-out rib fractures. However, in their study the diagnosis of rib fractures did not result in differences of the length of hospital stay, intensive care unit (ICU) admission rate or in-hospital mortality, which was remarkably higher—by 10.3%—in patients with CT-detected rib fractures [10]. Further studies on blunt trauma patients of every age have demonstrated that chest XR misses rib fractures and relevant intrathoracic injuries in blunt trauma patients of every age [27–29]. The proportion of undiagnosed rib fractures in chest XR ranges from 45% [29] to 74.5% (median three additional fractures in CT) [27]. Intrathoracic injuries have been CT-identified in 26% of the cases [28], leading to changes in clinical management in 8% [28], respectively 34.5% [27] of the cases. Additionally, it has been demonstrated that mortality increases by 19% with each additional rib fracture in older patients with blunt trauma [30]. Bearing this in mind, it appears to be clinically relevant to know whether one or two ribs are fractured or three and more, defining a multiple or serial rib fracture. The latter represents a severe blunt chest trauma with different prognostication, requirement for more aggressive pain management and functional therapy and the potential for surgical intervention in case of more part fractures or fracture displacement.

We found the prevalence for cervical spine fractures to be lower by 1.4%. CT examination of the cervical spine has been performed in 98% of cases when imaging of the cervical spine is required according to clinical decision rules [31,32] and current guidelines [14,16]. Importantly, when XR of the cervical spine was performed prior to CT examination on physicians' decisions in 15 cases, XR missed one of three fractures. Due to the inferior diagnostic capability of XR to detect fractures of the cervical spine, first-line CT examination should be the emergency imaging modality of choice to detect or rule-out fractures in this vertebral column region.

Prevalence for fractures of the thoracic and lumbar spine is 2.2% and 2.5%, respectively. This is consistent with a multi-center trauma registry analysis showing prevalence of 1.8% for thoracolumbar spine fractures in older individuals with LEF and multi-level injuries in 9.6% of patients with vertebral fractures [33]. In our observation, XR is specific for fractures of the thoracic and lumbar spine, but cross-tabulation for sensitivity and calculations of the LR^{-} (thoracic spine: 0.6; lumbar spine: 0.4) demonstrate that XR is not capable to safely rule-out fractures of these regions. Our findings are supported by a recently published meta-analysis, which demonstrates a pooled LR^{-} of 0.43 for XR to detect fractures of the thoracolumbar spine in adults with blunt, high- and low-energy injury mechanisms [15]. Current guideline recommendations are inconsistent as regards imaging modalities. The Eastern Association for the Surgery of Trauma (EAST) practices CT examination as the screening modality of choice when imaging is deemed necessary in blunt trauma patients [17]. The recent National Institute for Health and Care Excellence (NICE)-guidelines recommend performing XR as the first-line investigation for individuals with suspected spinal column injury without abnormal neurological signs or symptoms in the thoracic or lumbosacral regions, and only perform CT when the XR is abnormal in this region [16]. Imaging approaches have to allow rapid and effective clinical decision-making and care [34]. To date, neither guidelines nor available evidence on imaging recommendations for blunt thoracolumbar injuries are satisfactory in quantity and quality, even less so in the older population [15]. Our data now add some new information concerning the older population and low-energy trauma based on a large cohort. However, patient-oriented benefit of a first-line CT examination and the clinical relevance of additionally detected fractures by CT remains to be defined.

With regard to diagnostic accuracy, reformatted thoracolumbar spine CT showed higher accuracy than the chest–abdomen–pelvis CT [15], with an unknown impact on clinical management. However, in this meta-analysis, the pooled LR^{+} was 81.1 (95% CI: 14.1–467.9) and the LR^{-} was 0.04 (95% CI: 0.02–0.08) for diagnosing thoracolumbar spine fractures with the chest–abdomen–pelvis CT. Taking into account these observations and our findings, prospective studies comparing first-line chest–abdomen–pelvis CT examinations with sequential scanning (XR before CT) should be performed in order to tackle the unsolved issue of the moderate diagnostic accuracy of XR in older patients. The improved accuracy of fracture detection using CT seems obvious, but patient-oriented outcomes, such as the number of interventions, the duration of immobility, and the incidence of institutionalization, are to be explored. In our opinion, CT examination should be considered when clinical suspicion is high for injuries of the axial skeleton or pelvic ring in more than one region, physical examination is inconclusive, and further CT examinations such as head and cervical spine CT are necessary in older patients with LEF.

Certainly, there is a trade-off between cost and radiation doses on the one hand, and diagnostic accuracy on the other. Our study demonstrated that the highest effective radiation doses were applied when only CT examinations were performed. This included trunk and whole body contrast enhanced CT examinations. Radiation doses in our study were less, as compared to an all-age major trauma population, which receives an estimated radiation dose of 20.9 mSv by whole body CT examinations [35]. Effective dose estimations of single body regions demonstrated that the highest doses were applied during CT examination of the thoracic and lumbar spine (see Tables S3 and S4). These findings are supported by a previous study, investigating the effective doses of CT scans performed for various musculoskeletal applications [36]. However, lifetime cancer risk from CT examination is the highest for a CT scan of the torso in females, 60 to 69 years of age, with lifetime cancer incidence of 3.6 per 10,000 individuals [37]. This is estimated as an overall "low" risk [38]. With increasing age, the risk constantly declines to "minimal" beyond the age of 90 [37,38].

Our study has several strengths, including a large consecutive sample from two typical European urban tertiary care centers, as well as rigorous chart review abstraction for inclusion criteria and key measurements. Nevertheless, the study is limited by its retrospective design and by initial patient selection. The first limitation is that our observation might underestimate the prevalence of fractures, since most patients and regions were only examined by XR. Secondly, the initial patient selection represents a potential risk for selection bias. However, this inclusion strategy did not miss any patient with the gold standard examination CT, which allows calculation of diagnostic accuracy measurements. The third limitation is that the clinical relevance of our findings remains unknown due to the retrospective approach. We analyzed the rate of surgical treatment by mapping patients into different subgroups of imaging work-up. Based on a logistic regression, we found no differences in the rate of intervention comparing the three groups (XR only, CT only, or XR before CT). From a surgeon's point of view, only accurate fracture diagnosis allows the evaluation of fracture stability and prognostication. Furthermore, decisions on interventions, communication with patients, and detection of potentially underlying osteoporosis are all based on a sound diagnosis [39]. Our study adds some insight into the diagnostic shortcomings of XR of the axial skeleton in the setting of emergency imaging of older adults after LEF and may facilitate argumentation for CT imaging in case of ambiguous XR findings.

5. Conclusions

In conclusion, our study demonstrates that one out of five older patients with LEF has sustained osseous injuries of the axial skeleton, the pelvic ring or the proximal long bones. Standard of care XR has moderate diagnostic accuracy in detecting fractures of the spine, pelvic ring, and rib cage. Supposing that accurate fracture diagnosis is favored in these patients as in any other age group, our findings warrant a higher radiation exposure applied by CT examinations in a first-line imaging approach. However, in order to assess patient-centered clinical outcomes [40] of different imaging strategies, as well as the potential trade-offs between resources, radiation, and fracture detection more broadly, prospective multicenter randomized clinical trials are needed. Subsequent results would help to determine preexisting conditions and risk factors in these patients (e.g., multimorbidity, dementia, manifested osteoporosis or polypharmacy), to elaborate and develop clinical decision rules adjusted to and appropriate for the older population.

Supplementary Materials: The following are available online at http://www.mdpi.com/2077-0383/9/1/97/s1, Supplementary Methods: Calculation of injury severity score and estimation of cumulative radiation doses, Supplementary Results: Baseline demographics, way of presentation, trauma mechanism and injury severity, Table S1: Center specific proceedings for emergency imaging (n = 4901), Table S2: Total numbers and percentages

(%) of accurate and inaccurate diagnosis in "XR before CT examination" imaging processes (n = 540), Table S3: Comparison of effective dose estimations (mSv) (median, IQR) per patient (n = 2484), Table S4: Summary of effective dose estimations (mSv) (median, IQR) depending on body region (in n = 2484 patients) in comparison to previously published data (mean, standard deviation).

Author Contributions: Conceptualization, V.P., C.H.N., R.B., C.T., C.K., and W.B.; methodology, V.P., C.H.N., and R.B., formal analysis, A.L., I.A., N.M., S.N., and V.P., investigation, A.L. and V.P., resources, C.T., R.S., and A.E., data curation, A.L. and V.P., writing—Original draft preparation, A.L. and V.P., writing—Review and editing, V.P., C.H.N., R.B., C.K., and W.B.; visualization, A.L. and V.P., supervision, V.P., C.H.N., and R.B.; funding acquisition, V.P. and R.B. All authors have read and agreed to the published version of the manuscript.

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Anhang B: Veröffentlichung 2

diagnostics

MDPI

Article

Incidental CT Findings in the Elderly with Low-Energy Falls: Prevalence and Implications

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Abstract: Background: Computed tomography (CT) is commonly used in trauma care, with increasing implementation during the emergency work-up of elderly patients with low-energy falls (LEF). The prevalence of incidental findings (IFs) resulting from CT imaging and requiring down-stream actions in this patient cohort is unknown. We have investigated the prevalence and urgency of IFs from emergency CT examinations in these patients. Methods: A total of 2871 patients with LEF and emergency CT examinations were consecutively included in this retrospective cohort study. The primary endpoint was the prevalence of IFs; the secondary endpoint was their urgency. Results: The median age was 82 years (64.2% were women). IFs were identified in 73.9% of patients, with an average of 1.6 IFs per patient. Of all IFs, 16.4% were classified as urgent or relevant, predominantly in the abdomen, chest and neck. Increasing age was associated with the prevalence of an IF (odds ratio: 1.053, 95% confidence interval: 1.042–1.064). Significantly more IFs were found in female patients (75.2% vs. 71.5%). Conclusion: IFs resulting from CT examinations of the elderly are frequent, but in more than 8 out of 10, they are harmless or currently asymptomatic. For the benefit of an accurate diagnosis of traumatic lesions, concerns about IFs with respect to disease burden, further work-up and resource utilisation might be disregarded.

Keywords: incidental findings; older adult; low-energy fall; emergency imaging; computed tomography

1. Introduction

Computed tomography (CT) is a commonly used imaging modality in trauma care. Especially in patients suffering from high-energy trauma, whole-body CT (WBCT) scans are increasingly used and recommended by guidelines due to their real-time detection of acute traumatic injuries (ATI) with high specificity and sensitivity and their widespread availability [1–4]. However, besides their associated radiation exposure [1,2], WBCT scans are likely to reveal incidental findings (IF) unrelated to the preceding trauma [5–17]. Incidental findings are defined as recently unknown abnormalities revealed unintentionally in medical examinations. Their severity varies from harmless findings to ones requiring urgent treatment and follow-up. Several studies have reported on the prevalence and impact of IFs in predominantly severely injured trauma patients who received WBCT or selective CT scans as initial emergency imaging modality [5,6,8–10,18]. The prevalence of IFs in different trauma patient populations varies from 30.4% to 75.3% [5,6,8–10,12–16,18–21], with more findings detected by means of WBCT than by selective CT scans [10]. An amount of 1% to 46.9% of IFs could have an impact on patients' health and require urgent treatment or further examination [5,10,11,17]. Interestingly, in chest CT performed on trauma patients, IFs are much more common than ATI; known relevant diagnoses, histories of smoking, and age serve as predicting factors for IFs [22].

Accurate and efficient emergency imaging of older adults presenting to the emergency department (ED) due to low-energy falls (LEF) is of increasing importance considering the general demographic development [23,24]. Due to certain limitations of the diagnostic accuracy of plain radiography, particularly in the thorax, spine and pelvic region [25–27], selective CT or unenhanced WBCT scans are frequently applied sequentially for diagnostic assurance [26]. Therefore, first-line WBCT or selective CT scans of selected older adults with LEF become increasingly important in daily practice in the emergency imaging setting. However, weighing the benefits of timely and accurate diagnosis of injuries against the disadvantages or harm of radiation exposure and IFs requiring downstream examinations [28] is obligatory for both emergency physicians and radiologists. So far, to the best of our knowledge, neither the distribution of IFs revealed by emergency CT scans nor their importance and relation to age and sex in older adults with LEF has been investigated systematically.

The objectives of this study were to assess, firstly, the prevalence of incidental CT findings in different body regions and, secondly, their urgency, regional distribution and relation to age and sex in a large cohort of elderly patients presenting with LEF to the ED.

2. Materials and Methods

2.1. Study Design

This is a secondary analysis of a bicentric, binational retrospective study carried out in two university tertiary care hospitals in Switzerland (University Hospital Basel) and Germany (University Hospital of Ludwig-Maximilians-University Munich) using electronic health records (EHRs). The study is in accordance with the declaration of Helsinki and was conducted using STROBE guidelines. Ethics approval was obtained from local ethics committees (EKNZ 2017-01078 approved 12 July 2017, EK LMU 17-217, approved 10 May 2017).

2.2. Study Population

Parts of the methods used in this study have been previously described [26]. In short, patients aged 65 years and older who suffered from LEF (falls from standing height, falls out of bed/from chairs/wheelchairs or other low-level furniture or falls from a low level less than 1 m [26]) and underwent CT examination of the head, cervical spine, chest, abdomen/pelvis and/or total body within 48 h of the index visit to the ED between 1 January 2016 and 31 December 2016 were consecutively included. Patients referred from another hospital with preceding imaging, patients who required trauma team activation, and patients with a delayed presentation (≥8 days after the fall) were excluded from this study.

2.3. Data Collection

Patients aged ≥65 years receiving a CT examination in one of the two hospitals within 48 h after admission in this 1-year-period were screened for inclusion using our radiology information systems (RIS) [26]. All EHRs of included cases were screened for validated CT reports from board-certified radiologists within 48 h of the index visit. Each of the identified CT reports was reviewed for documented IFs by two of the three trained non-blinded reviewers independently (S.N., R.W. and V.P.). An IF was defined as any finding not related to the trauma [20], independent of whether this finding might affect the patient's health or not. When available, prior reports were checked to ensure the findings were new. Furthermore, EHRs were searched for delayed reported IFs during follow-up CT examinations. In the case of documented IFs, EHRs were searched for downstream examinations during the index admissions. Board-certified radiologists' recommendations for additional imaging examinations were documented. Disagreements or equivocalness about the IFs and the categorisation of the IFs were decided upon by a third observer (V.P. and S.N.) by reviewing the CT images. Screening and chart review abstraction were conducted in accordance with the recommendations for medical chart review [29,30], which were fulfilled for 11 of 12 guidelines (abstractors were not blinded to the hypothesis). Data entry was performed in a Microsoft Access 2010/2016 database (Microsoft, Redmond, Washington, USA).

2.4. Incidental Findings and Categorisation

Incidental findings were categorised in accordance with a previously published study [8]. According to this, category 1 IFs were defined as findings with the need for urgent treatment or further examinations; category 2 IFs were defined as findings with the need for follow-up examinations within 3 to 6 months; category 3 IFs were defined as asymptomatic but potentially relevant in the future; and category 4 IFs were defined as harmless with no further investigation needed. The distinction between category 1 and 2 findings was made upon the board-certified radiologists' recommendations for additional examinations and their scheduling in the CT reports and in the case of category 1 IFs documented down-stream treatments or examinations related to the findings (e.g., magnetic resonance tomography examinations, vascular intervention or diuretic treatment or drainage therapy of lung oedema or pleural effusion) during the index visit. Additionally, current guidelines and classification systems were applied for pulmonary nodules and renal cysts [31,32]. The default of the database entry template was designed considering the most common findings of the analysed body regions (head, neck, chest, abdomen including the pelvic region and spine) published previously [7], expecting comparable IFs in our cohort. Other IFs that were not listed were specified and categorised separately.

2.5. Key Outcome Measures

The primary endpoint of the study was to assess the prevalence of IFs in emergency CT imaging of older adults with LEF. The secondary outcomes were to determine the most common findings, their regional distribution, their urgency, and their relation to age and sex.

2.6. Statistics

For descriptive statistics, median and interquartile ranges (IQRs) were used to report continuous and ordinal data, where applicable. The Pearson Chi^2 test with continuity correction or the Fisher's exact test was used for the comparison of categorical data, with Bonferroni correction for multiple comparisons. Interrater agreement between reviewers was determined by calculating unweighted Cohen's κ coefficients in a subsample of 868 patients for identification of IFs on CT reports using a corresponding 95% confidence interval (95% CI). All identified statistically significant risk factors (age, age category, sex) were chosen as covariates for the subsequent regression. For the outcome, IF multivariate logistic regression models were calculated and adjusted for age and sex. p values < 0.05 were considered significant. Statistical analyses were performed using SPSS Statistics 26 and RStudio version 1.4.1.

3. Results

We included 2871 patients in the analysis (Figure 1). The median age was 82 years (range 65–105; IQR 76–88), and 64.2% of included patients were women. Table 1 shows baseline demographic information. Cohen's unweighted κ for the interrater agreement was 0.83 (95% CI: 0.79–0.87) for identification of IF on CT report. In total, 2122/2871 (73.9%) patients were identified with having IFs. The most frequent examinations were CT of the head (2549) and neck including the cervical spine (1614). CT examinations of the chest and abdomen (including the pelvic region) were performed in 262 and in 149 patients, respectively. Incidental findings in the thoracic and lumbar spine were registered in the CT scans of the selected spine regions or in the corresponding scans of the chest and abdomen.

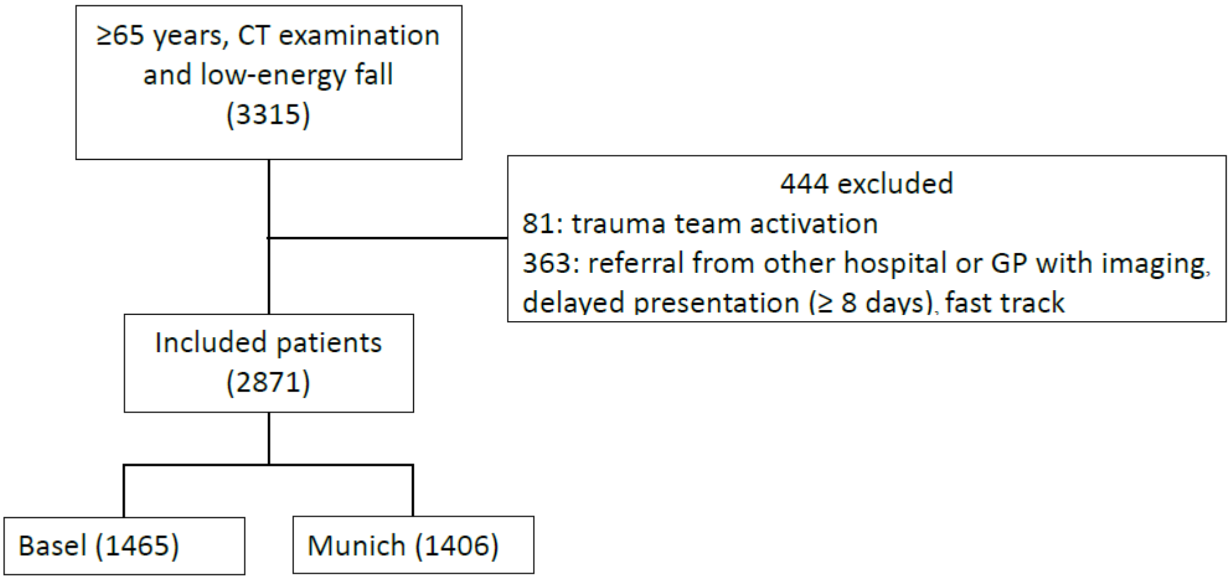

Figure 1. Inclusion and exclusion flow diagram of patient selection from 1 January 2016 to 31 December 2016 in Basel and Munich, with patients receiving computed tomography (CT) examinations of the head, spine, chest, abdomen, pelvic ring or proximal long bones during emergency department presentation or within 48 h.

Table 1. Baseline characteristics of 2871 elderly adult patients presenting with low-energy falls from 1 January 2016 to 31 December 2016.

Characteristics	Total (n = 2871)	Basel (n = 1465)	Munich (n = 1406)
Age (median, IQR)	82 (76–88)	82 (70–94)	81 (68–94) [b]
65–74 (%)	616 (21.5)	319 (21.8)	297 (21.1)
75–84 (%)	1146 (39.9)	555 (37.9)	591 (42.0)
>85 (%)	1109 (38.6)	591 (40.3)	518 (36.8) [c]
Female (%)	1842 (64.2)	936 (63.9)	906 (64.4) [a]

If not otherwise stated, data are reported as number of patients (%). [a] p = 0.76 (Pearson Chi^2 test) between centres, [b] p = 0.39 (t-test) between centres, [c] p = 0.064 (Pearson Chi^2 test) between centres and age categories. IQR: interquartile range.

Table 2 summarises the prevalence of IFs in the examined body regions. Overall, 3488 IFs in 2122 patients (on average, 1.6 IFs per patient) were found. Of these 3488 findings, 264 (7.6%) were classified as category 1, 307 (8.8%) as category 2, 2740 (78.5%) as category 3, and 177 (5.1%) as category 4 findings (Table 3).

Table 2. Summary of the prevalence of incidental findings per age group and per examination of different body regions (number of examinations).

Incidental Findings	Patients with An IF (%)
Overall	2122/2871 (73.9)
65 to 74 years	387/616 (62.8%)
75 to 84 years	818/1146 (71.4%)
≥85 years	917/1109 (82.7%)
	Per CT Examination (%)
Head CT (n = 2549)	1677/2549 (65.8)
Cervical spine CT (n = 1614)	179/1614 (11.1)
Chest CT chest (n = 262)	196/262 (74.8)
Abdomen CT (n = 149)	116/149 (77.9)
Neck CT (n = 1614)	346/1614 (21.4)

CT: computed tomography; IF: incidental finding.

Table 3. Proportion of incidental findings per category according to [8].

Category	Definition	%
1	Urgent treatment or further examination	7.6
2	Follow-up within 3 to 6 months	8.8
3	Asymptomatic but potentially relevant	78.5
4	Harmless, no further investigation	5.1

Figure 2 summarises the frequencies of IF categories per region. A detailed summary of the total numbers and proportions of IFs per category in the respective regions is given in Table S1. Category 1 IFs were most frequently present in the CT scans of the chest and abdomen; category 2 IFs were most frequently found in the neck and chest. Category 3 IFs were most frequently present in the head and spine. Increasing age is associated with the prevalence of an IF (OR: 1.053, 95% CI: 1.042–1.064, $p < 0.001$), and in the age group of ≥85 years, an IF was located in 82.7% of patients.

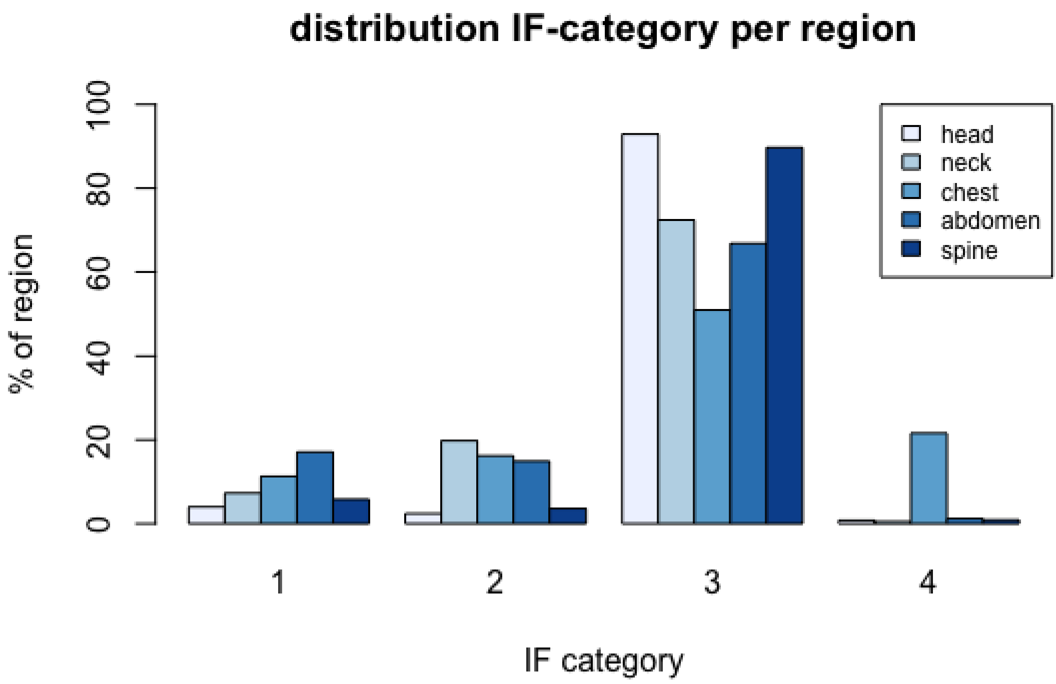

Figure 2. Distribution of incidental finding (IF) categories per body region investigated.

Figure 3 summarises the proportions of IF categories by age group. A detailed summary of numbers and proportions of the severest IFs per region and age group is given in Table S2. Significantly more IFs of any category were found in female than male patients (75.2% vs. 71.5%) (Chi^2: 4.73, df: 1, $p = 0.03$). There was no significant relation between age and sex and the severity of IFs in the head and the abdomen. In the neck region significantly more category 2 IFs were detected in female subjects (26.2% vs. 6.1%), and more category 3 IFs were detected in male subjects (86.1% vs. 65.5%; Chi^2: 21.35, df: 3, $p < 0.001$). In the chest region, significantly more IFs of category 4 were detected in female subjects (22.9% vs. 11.4%; Chi^2: 12.09, df: 3, $p < 0.05$). A detailed summary of numbers and proportions of the severest IFs per region and sex is given in Table S3. Significant relationships between age (Chi^2: 22.45, df: 6, $p = 0.001$) and female sex (Chi^2: 9.64, df: 3, $p = 0.022$) and IFs in the spine regions were measured. More category 3 IFs were detected in the oldest (93.8%) and female subjects (92.0% vs. 82.7%). Tables 4 and 5 summarise the most frequent IFs per region and the most frequent category 1 and 2 findings per region.

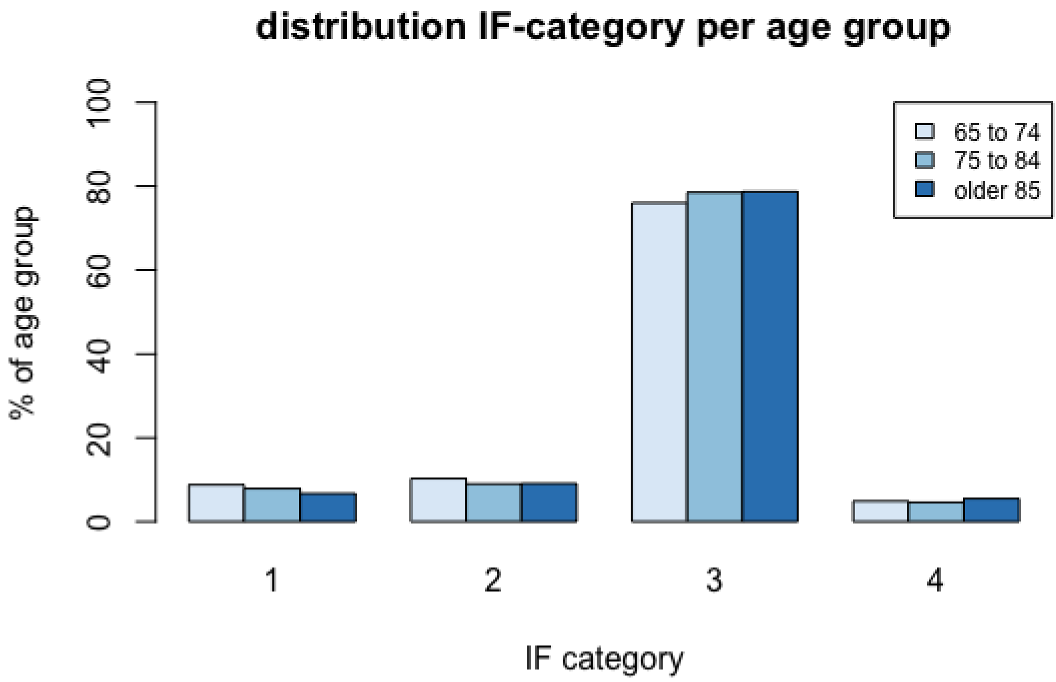

Figure 3. Distribution of incidental finding (IF) categories per age group.

Table 4. Top 5 incidental findings per region.

Head (n = 1726)	Neck (n = 399)	Chest (n = 717)	Abdomen (n = 422)	Spine (n = 224)
Microangiopathy (1216) Previous cerebral infarction (310) Atherosclerosis (intracranial carotid artery, circle of Willis) (223) Lacunar lesions (124) Meningioma (65)	Atherosclerosis (extracranial carotid artery) (188) Multinodular goitre (100) Goitre (75) Regressive thyroid changes (70) Calcified thyroid nodule (13)	Atherosclerosis (aorta and branches) (254) Pleural scarring (173) Coronary artery calcification (137) Pleural effusion (118) Cardiomegaly (75)	Atherosclerosis (aorta and branches) (156) Diverticulosis (114) Kidney cysts (97) Liver cysts (40) Hiatal hernia (37)	Severe foraminal stenosis (60) Disc protrusion (20) Osseous lesion (9) Pars defect (9) Schmorl node (9)

Table 5. Top 5 incidental findings per region categorised 1 and 2.

Category	Head	Neck	Chest	Abdomen	Spine
1	***n* = 69**	***n* = 29**	***n* = 81**	***n* = 72**	***n* = 13**
	Brain masses (31) Metastases/Osteolysis (10) Suspected normal pressure Hydrocephalus (8) Meningioma (6) Atherosclerosis (intracranial carotid artery, circle of Willis) (6)	Atherosclerosis (extracranial carotid artery) (8) Multinodular goitre (7) Mass (5) Lymphadenopathy (4) Hypodense thyroid lesion (2)	Infiltrates/Pneumonia (44) Lymphadenopathy (13) Lung nodules (12) Pleural effusion (11) Pulmonary oedema (8)	Mass/Metastases (13) Solid liver lesion of unclear aetiology (11) Adrenal myolipoma (10) Renal mass (9) Abdominal aortic aneurysm (6)	Osteolysis (8) Mass (4) Suspected Myelopathy (1)
2	***n*= 41**	***n*= 79**	***n*= 116**	***n*= 63**	***n*= 8**
	Meningioma (16) Suspected normal pressure hydrocephalus (12) Mass (9) Cerebral artery aneurysms (7) Atherosclerosis (intracranial carotid artery, circle of Willis) (2)	Multinodular goitre (34) Atherosclerosis (extracranial carotid artery) (17) Goitre (13) Hypodense thyroid lesions (10) Thyroid mass (6)	Lung nodules (47) Aortic lesions (18) Cardiomegaly (18) Aortic ectasia (14) Lymphadenopathy (8)	Abdominal aortic aneurysm < 4 cm (16) Prostate hyperplasia (8) Solid liver lesion (suspected for haemangioma) (7) Liver cyst (6) Hiatal hernia (4)	Severe foraminal stenosis (3) Distracted disc space (3) Haemangioma (1) Atypical haemangioma (1)

4. Discussion

To the best of our knowledge, this is the first study examining the prevalence of IFs in older adults presenting to the ED with LEF and undergoing emergency CT scans for the detection of traumatic lesions. The main result of this study is that 73.9% of included patients had at least one IF in the examined body regions. Most IFs were seen in the abdomen, chest and head, and the vast majority of IFs detected were of minor impact, not requiring further diagnostics or treatment. Our data demonstrate age is a risk factor for IFs and that sex is related to IFs in certain body regions.

The overall IF prevalence of 73.9% in our study is confirmed by two other previously published studies in which 75% of patients undergoing WBCT scans showed IFs [5,8]. Several other authors [6,9–16,18–21] reported fewer occurrences of IFs, ranging from 15.9% [11] to 54.8% [16], regardless of whether WBCT or selective CT scans were conducted. A direct comparison of the prevalence of the above-mentioned studies is difficult due to varying patient inclusion criteria and general exclusion of certain diagnostic findings, such as degenerative joint diseases, age-related cerebral atrophy and atherosclerotic changes [6,7,10,12].

In line with previous studies [8,10,11,17,33], our analysis demonstrated that, besides the head, CT examinations of the abdomen and chest revealed the highest rates of IFs. This is presumably explainable by a large number of different visceral organs and tissues in the abdomen and chest.

Our evaluation indicated that 7.6% of IFs were identified as category 1, comprising patients requiring an urgent treatment or examination. This corresponds to previous results [6–11,15,16,20,21] reporting high urgency IFs in 2 [11] to 12.5% [7]. Most category 1 findings were found in the chest, followed by the abdomen and the head (see Figure 2), notably consisting of malignancies and pneumonia. Likewise, category 2 findings were located predominantly in the neck, chest and abdomen (see Figure 2). Lung nodules represent the majority of this severe category, followed by multinodular goitre and vascular abnormalities such as aortic elongations, ectasia and aneurysms. In total, 16.4% of IFs were categorised as urgent or relevant, demanding short-term treatment or follow-up investigations. Three considerations are relevant to the most common IFs in these categories.

Firstly, the most common IFs concern findings that respond well to treatment, such as pneumonia and multinodular goitre, and thus could have a positive impact on patients' lives. Secondly, it is possible that these findings will become symptomatic sooner or later, where later detection could worsen the outcome [34]. However, in the case of the very old, the benefit of this observation must be questioned because the diagnosis may not be life-limiting. Thirdly, since in most of the older adults with LEF, the origin of the falls remains unclear [23], some of the IFs may refer to the condition underlying the fall, e.g., an acute infection.

It should be noted that 83.6% of all IFs are category 3 and 4, thus currently asymptomatic or harmless. It can be assumed that these IFs with low impacts represent the average prevalence of certain age-related morbidities such as vascular diseases. Some of these may have already been diagnosed and treated so that no additional effort and resource utilisation is expected. In our own experience and consistent with other authors [6–8,10,12–14,17,34], a lack of systematic documentation and communication of IFs is evident, demanding digital solutions and general guidelines about communication of IFs [22]. The median age of our retrospective study cohort was 82 years; as a result, this analysis of IFs has the oldest trauma population published so far. Our data demonstrate that increasing age constitutes a risk factor for the detection of IFs in emergency CT imaging. This is confirmed by several previous studies in trauma [5,7–9,11,13,15,16,20,34,35] and mixed cohorts [17] with mean ages ranging from 36 [7] to 63 years [5]. Age was identified as an independent risk factor of IFs [17], not only in age groups but also in every year of increasing age [11,33]. Furthermore, a correlation between increasing age and severity of the IFs has been reported previously [8,9]. In our data, this could only be confirmed in spine CT examinations. Our in-depth analysis of IF severity revealed that category 3 IFs are more frequent in the oldest patients (85 years and older), whereas category 1 IFs (e.g., osteolysis, unclear masses) are more frequent in the youngest age group (65 to 74 years).

Our study adds to existing data regarding the relation between sex and IF category in certain body regions. According to this, female subjects have a higher risk of category 2 IFs in the neck, mainly multinodular goitre and thyroid lesions. The latter reflects the known higher prevalence in females of thyroid-associated diseases.

Based on this and previous studies, medico-economic impacts such as cost–benefit and medical benefit–burden ratios resulting from the detection of IFs in imaging studies remain unclear. It has been demonstrated that between 5.3% [17] and 6.2% [33] of all detected IFs generate additional investigations or clinical actions in their respective institutions. Based on this, an average cost of EUR 2292 per IF, which triggered down-stream actions, has been calculated in a mixed ED cohort [17]. However, with regard to all detected IFs, average costs would amount to EUR 121 per IF detected in this study. With regard to medical benefits or burdens, clear medical benefits have been determined for 1% of the cases, whereas clear medical burdens were determined for 0.5% of the cases, and in 4.6% of the instances, benefit–burden ratios were unclear [33]. It must be taken into account that an IF detected by a recent CT examination, which is clarified and documented systematically, would therefore no longer require cost-intensive clarifications in later stages. To address this properly, well-designed prospective cost–benefit and cost-effectiveness studies are needed.

Our study has several strengths, including a large consecutive sample of a representative population with rigorous chart review abstraction of key outcome measurements. On the other hand, the study is limited by its retrospective design without the systematic follow-up of patients and the initial patient selection representing a potential selection bias, as stated previously [26]. The selection of patients with unclear abdominal or thoracic complaints who received specific CT examinations may reveal a different pattern of IFs and severity. Furthermore, only selective CT scans were analysed. Thus, the prevalence of IFs can only be related to the examinations performed, resulting in a selection bias and a possible underestimation of the actual prevalence of IFs. This assumption is supported by a previous study where higher IF rates were found in WBCT compared to selective CT scans [10]. Additionally, since digital patient reports are not generally available, it is possible that our findings are pre-known diagnoses, which in some cases may result in over-reporting.

5. Conclusions

In conclusion, our study demonstrates that IFs revealed by emergency CT examinations in elderly adults are frequent, depicting increasing prevalence with increasing age. Of these, more than 8 out of 10 IFs are harmless or currently asymptomatic with potential impacts in the future and reflect the most common underlying age-related conditions such as vascular changes. According to our data, less than 2 out of 10 IFs require down-stream examinations or treatments. Considering the growing utilisation of emergency CT examinations in elderly adults with LEF, the concerns about IFs with respect to disease burden, necessary further work-up and resource utilisation might be disregarded when compared to the benefits of an accurate and prompt diagnosis of traumatic lesions.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/diagnostics12020354/s1, Table S1: Summary of total numbers and proportions (%) of incidental findings (IFs) per category, Table S2: Summary of numbers and proportions (%) of severest incidental findings per region and age group, Table S3: Summary of numbers and proportions (%) of severest incidental findings per region and sex.

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Institutional Review Board Statement: Thestudy was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee Northwest and Central Switzerland EKNZ and the Ethics Committee at the LMU Munich (EKNZ 2017-01078 approved 12 July 2017, EK LMU 17-217, approved 10 May 2017).

Informed Consent Statement: Patient consent was waived by the local ethics committees due to the retrospective and exploratory study design.

Data Availability Statement: Anonymized data presented in this study are available upon reasonable request from the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

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