DANISH MEDICAL JOURNAL

Original Article

Dan Med J 2023;70(4):A10220612

Positive predictive value of humeral fractures in the Danish National Patient Registry

Dennis Karimi[1], Line Houkjær[2], Per Gundtoft[3], Stig Brorson[2] & Bjarke Viberg[1, 4]

1) Department of Orthopaedic Surgery and Traumatology, University Hospital of Southern Denmark – Hospital Lillebaelt, 2) Centre for Evidence-Based Orthopaedics, Zealand University Hospital, 3) Department of Orthopaedic Surgery and Traumatology, Aarhus University Hospital, 4) Department of Orthopaedic Surgery and Traumatology, Odense University Hospital, Denmark

Dan Med J 2023;70(4):A10220612

ABSTRACT

INTRODUCTION. The purpose of this study was to validate the humeral fracture diagnoses for adults in the Danish National Patient Registry (DNPR).

METHODS. This was a population-based validity study, including adult patients (≥ 18 years) with a humeral fracture referred to the emergency department of hospitals in three Danish regions from March 2017 to February 2020. Administrative data were retrieved on 12,912 patients from the databases of the involved hospitals. These databases hold information on discharge and admission diagnoses, which is based on the International Classification of Diseases, tent version. Data of 100 cases were randomly sampled from each of the specific humeral fracture diagnoses (S42.2-S42.9). The positive predictive value (PPV) was estimated for each diagnosis to study the recorded accuracy. Radiographic images from the emergency departments were reviewed and assessed as the gold standard. The PPVs with 95% confidence intervals (CI) were estimated according to the Wilson method.

RESULTS. In total, 661 patients were sampled between all available diagnosis codes. Overall, the PPV for humeral fracture was 89.3% (95% CI: 86.6-91.4%). PPVs for the subdivision codes were 91.0% (95% CI: 84.0-95.0%) for proximal humeral fractures, 89.0% (95% CI: 81.0-94.0%) for humeral diaphyseal fractures and 78.0% (95% CI: 68.9-84.9%) for distal humeral fractures.

CONCLUSION. The validity of the humeral fracture diagnosis and the classifications of proximal and diaphyseal fractures in the DNPR is high, and the DNPR may therefore be used in registry research. Diagnosis of distal humeral fractures has a lower validity and should be used with caution.

FUNDING. none.
TRIAL REGISTRATION. not relevant.

National patient registers are a key tool in healthcare planning by monitoring the frequency of various diseases and treatments, thereby providing patient data to support hospital statistics and enable financial calculations [1]. Furthermore, the national registries are increasingly being used for population-based research [2]. To guarantee a meaningful use and interpretation of data from the clinical quality databases, knowledge of data validity is essential.

Data validity in registers include coverage, completeness of patient diagnoses and other recorded variables, and

correctness of the recorded data [2].

The Danish National Patient Registry (DNPR) has nationwide coverage since all hospitals are reimbursed by the government when patient data are recorded to the registry [3, 4]. The diagnosis completeness for conditions that should lead to a hospital encounter is assumed to be high owing to the free universal Danish healthcare system [5]. Assessment of data correctness is an ongoing task, which requires frequent validation [6].

A limited number of studies have validated orthopaedic diagnoses from the DNPR [3, 7-10]. In 2006, Lass et al. reported a positive predictive value (PPV) of 86% for all orthopaedic diagnoses imported to the DNPR in a two-week time period [7]. In 2020, Hjelholt et al. studied the validation of hip fracture diagnoses from the DNPR and reported PPVs ranging from 83% to 92% depending on the anatomical location of the proximal femur [8]. This shows that the accuracy of registered diagnoses to the DNPR may vary by fracture location, which may also be the case for humerus fractures.

To our knowledge, no validation study exists on fracture diagnoses of the humerus in the DNPR. The purpose of this study was to validate the humeral fracture diagnoses for adults in the DNPR by estimating the PPV.

METHODS

Design

This was a population-based validity study. The study conforms with the Standards for Reporting Diagnostic accuracy studies [11]. Institutional approvals were obtained from all participating departments. The management of personal data was approved by the Data Protection Agency (ref. no.: 21/16771).

Setting

Danish healthcare provides free access to general practitioners and hospitals for all Danish residents, including orthopaedic services. Denmark is divided into five regions with a substantial homogeneity in sociodemographic and health-related characteristics [12]. The present study was conducted in three Regions of Denmark (Capital Region, Region of Southern Denmark and Region of Zealand) with a total population of 3.1 million adults [13].

Study population

The study population consisted of adult patients (≥ 18 years) referred to the emergency department with a primary or secondary first-time diagnosis of a humeral fracture to one of the included hospitals. Administrative data were retrieved from hospital databases that recorded discharge and admission diagnoses from 1 March 2017 to 29 February 2020. The data included identification number, sex, contact date and registered diagnosis code for a humerus fracture (S42.2, S42.3, S42.3A, S42.4, S42.7, S42.7B S42.8, S42.9). Data relating directly to fractures of the scapula or clavicle were excluded (S42.0, S42.1, S42.7A and S42.7C).

From this source population, the data of 100 cases were randomly sampled from each of the specific humeral fracture diagnoses (S42.2-S42.9) to study the recorded accuracy of each diagnosis. If less than 100 cases were registered for one of the specific diagnoses, all cases for that specific diagnosis were included.

Review of radiographic images

Radiographic images from the emergency department were reviewed and assessed as the gold standard for the diagnoses. In few cases, computed tomographies were the primary imaging modality. The review of radiographic images was completed independently by two authors (DK, LH). Firstly, assessing if the fracture involved the humeral bone (S42*, Humeral fracture); secondly, if the diagnosis from the DNPR was correct. In case of disagreement, the cases were discussed between the two reviewers; and if a consensus could not be

reached, a second independent review of the disagreed cases was conducted by three other authors (PG, SB, BV) and discussed until consensus. The diagnoses in the DNPR were assessed and defined as described by the AO/OTA Classification (version 2018) for fracture localisation of bones and segment [14]. All bones and segments are numbered sequentially from proximal to distal. To determine the location of end segments, a quantifiable method is proposed by the AO/OTA to distinguish between anatomical segments by Heim's system of squares. The proximal and distal segments are inside a square, and the length of the sides are defined by the widest part of the epiphysis.

Humeral fracture codes

The Danish Medical Coding Classification System is based on the International Classification of Diseases, tenth revision (ICD-10) with an extra subdivision that includes a suffix alphabetic letter [15, 16]. Fractures of the shoulder and upper arm have eight subdivisions by the ICD-10. These subdivisions range from specific anatomic segments of the clavicle bone, scapula bone and humeral bone (proximal, diaphyseal and distal) to unspecified subdivisions including multiple fractures of clavicle, scapula and humerus; fractures of other parts of shoulder and upper arm; and unspecified fractures of the shoulder and upper arm [15]. In two diagnoses: S42.3A (Fracture of the humerus unspecified) and S42.7B (Multiple fractures of the humerus), the suffix was kept since removal of the letter would change the definition of the fracture location.

The Danish National Patient Registry

From 1977 to 1993, the DNPR collected discharge diagnoses on individual patients according to the ICD-8. Thereafter, the ICD-10 has been used. The registry makes it possible to follow a patient's healthcare contacts longitudinally by individual-level linkage to the Danish Civil Registration System, which provides all persons residing in Denmark with a unique ten-digit Civil Personal Register (CPR) number [17]. Hospitals in Denmark are compelled by law to report data to the DNPR and the registry is updated continuously on a weekly basis by hospital administrations. The registry has a nationwide coverage from public hospitals of 99.7%, and since 2003 it has also been mandatory for private hospitals to use the register [3]. In combination with the universal healthcare system of Denmark, this lowers the selection bias of the registry for all hospital-treated conditions. Fractures of the upper arm are conditions that should always lead to a hospital visit for diagnostics and initial treatment, as it is possible to obtain emergency radiographic images of the humerus only in public hospitals in Denmark. Therefore, we assume that the coverage of upper arm fractures in the DNPR is close to 100%.

Statistical analysis

The PPV with 95% confidence intervals (CI) was estimated according to the Wilson method [18]. The PPV was first estimated as the proportion of humeral fracture diagnoses (S42*) retrieved from the DNPR that was correctly reported as a humeral fracture. Furthermore, the correctness of the specific fracture diagnosis from the DNPR was assessed against the correct anatomical location of the fracture.

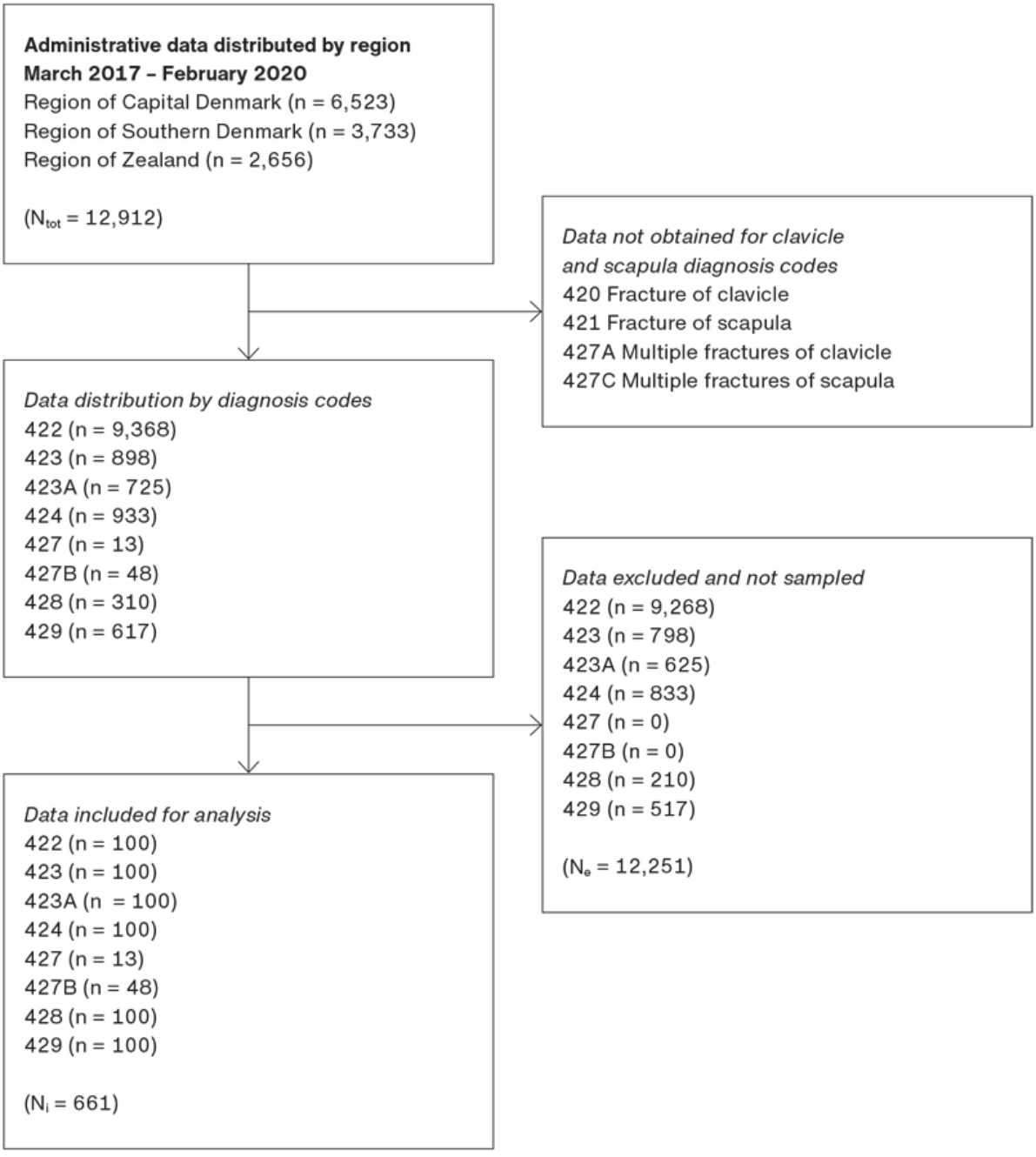
The patients were sampled using Microsoft Excel 2010 (Microsoft Corp, Redwood, Washington) and analysed using STATA statistical software, V17 (StataCorp, LP).

Trial registration: not relevant.

RESULTS

A total of 12,912 patients were identified with a humeral fracture diagnosis from March 2017 through February 2020. The distribution between regions was: 50.5% Capital Region, 28.9% Region of Southern Denmark and 20.6% Region of Zealand. In total, 661 patients were sampled between all available diagnosis codes (**Figure 1**).

FIGURE 1 Flow chart of patients with a humeral fracture diagnosis code.



The PPV for humeral fracture was 89.3% (95% CI: 86.6-91.4%). The PPVs for subdivision codes were 91.0% (95% CI: 84.0-95.0%) for proximal humeral fractures, 89.0% (95% CI: 81.0-94.0%) for humeral diaphyseal fractures and 78.0% (95% CI: 68.9-84.9%) for distal humeral fractures (**Table 1**).

TABLE 1 Positive predictive values for humeral fracture diagnosis codes in the Danish National Patient Registry.

		Any humeral fracture, S42		Specific humeral fracture, S42.x	
Diagnosis code	n	verified as, n	PPV, %	verified as, n	PPV (95% CI), %
S42.2	100	97	97	91	91 (84.0-95.0)
S42.3	100	98	98	89	89 (81.0-94.0)
S42.4	100	89	89	78	78 (68.9-84.9)
S42.3A	100	99	99	-	-
S42.7	13	0	0	-	-
S42.7B	48	47	98	-	-
S42.8	100	77	77	-	-
S42.9	100	83	83	-	-
S42, total	661	590	89	-	- (86.6-91.4)

CI = confidence interval; PPV = positive predictive value.

The distribution by humeral fracture segments was: 52% proximal fractures, 24% diaphyseal fractures, 14% distal fractures, 2% clavicle fractures, 4% scapula fractures and 4% other injuries (**Table 2**). PPVs for humeral fractures per calendar year were as followed; 2017, 92.2% (95% CI: 81-92%), 2018, 92.5% (95% CI: 87-94%), 2019, 89.7% (95% CI: 85-93%) and 2020 88.9% (95% CI: 70-90%).

TABLE 2 Distribution of the Danish National Patient Registry codes against gold standard assessments for humeral fractures. The values are n (%)

Diagnosis code	S42.0	S42.1	S42.2	S42.3	S42.4	Other
Specified codes						
S42.2			91 (91)	6 (6)		3 (3)
S42.3	1 (1)		9 (9)	89 (89)		1 (1)
S42.4			4 (4)	7 (7)	78 (78)	11 (11)
Unspecified codes						
S42.3A			63 (63)	32 (32)	4 (4)	1 (1)
S42.7	7 (54)	5 (38)				1 (8)
S42.7B			25 (52)	16 (33)	6 (13)	1 (2)
S42.8	7 (7)	13 (13)	69 (69)	6 (6)	2 (2)	3 (3)
S42.9	1 (1)	10 (10)	81 (81)	2 (2)		6 (6)
Total distribution	16 (2)	28 (4)	342 (52)	158 (24)	90 (14)	27 (4)

DISCUSSION

The DNPR accurately recorded diagnoses of humeral fractures during 2017-2020 with a PPV of 89%. The PPVs for fracture-specific locations ranged from 78% to 91%. The study could document a high validity for proximal and diaphyseal humeral fractures; 91% and 89%, respectively. The high validity suggests that the DNPR is a reliable

registry for epidemiological research on humeral fractures and for proximal and diaphyseal humeral fractures. However, distal humeral fractures presented a lower validity of 78%, and this diagnosis code should therefore be used with caution for registry research.

This was the first study to validate DNPR specifically for the diagnosis codes for humeral fractures. Previous validations studies of orthopaedic diagnoses in the DNPR have shown acceptable PPVs that are among the highest compared with other fields [3]. Our results show that the validity of the humeral fracture diagnosis is superior to what other existing DNPR validation studies have found for overall orthopaedic diagnosis codes [3, 7] and in line with the results of other validation studies assessing specific orthopaedic conditions [8-10].

The high validity of the humeral fracture diagnosis may be explained by the presentation of the condition. Patients with humeral fractures present themselves with symptoms of localised pain, and the fracture may be clearly visualised with radiographic images without overlap from other bones.

The accuracy decreased with the subclassification (proximal, diaphyseal, distal) of specific humeral fracture segments. Some of the variation in PPV for humeral fractures by anatomical location may be explained by fractures located on the border of the defined cut-offs [19].

Limitations and strengths

Several limitations and strengths should be considered.

1. The possibility to choose unspecified codes for humeral fractures in the ICD-10 may result in a reduced sensitivity for the main fracture segments (proximal, diaphyseal, distal). From Table 2, we can extract that 78%, 18% and 4% of unspecified humeral fracture diagnoses could have been diagnosed as proximal, diaphyseal and distal fractures, respectively. It remains unclear if the fracture morphology on correct registered proximal, diaphyseal and distal fractures differs from the unspecified diagnosis code since we did not assess fracture morphology. If fractures in the unspecified diagnosis group present more complex morphologies, this may be a limitation for future register-based studies that do not include these codes due to fracture heterogeneity.

2. The PPV was used as a measure of DNPR validity since the data collection was specifically related to diagnosis codes of humeral fractures. A high PPV validates the use of a diagnosis code for prognostic studies but cannot independently estimate disease prevalence or incidence.

3. Data were collected from only three of the five Danish regions as we did not have data on the last two regions. The Danish population is highly homogenous with respect to sociodemographic and healthcare utilisation between the five regions [12]. Therefore, the findings should be generalisable to the entire population.

Clinical implications

The high validity of humeral fracture codes in the DNPR enables the use of the database to conduct register-based studies that, e.g., identify risk factors for failure, monitor treatment trends and mortality rates. More validation studies on fracture diagnoses from the DNPR are needed to establish a gold standard for a future Danish Fracture Database with the potential of including fracture- and procedure-specific indicators and outcomes to study rare events and risk factors.

CONCLUSION

The validity of the humeral fracture diagnosis and the classifications of proximal and diaphyseal fractures in the DNPR is high, and the DNPR may therefore be used in registry research. The diagnosis of distal humeral fractures has a lower validity and should be used with caution.

Correspondence *Dennis Karimi*. E-mail: dennis.karimi@rsyd.dk

Accepted 15 February 2023

Conflicts of interest Potential conflicts of interest have been declared. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2023;70(4):A10220612

REFERENCES

1. Danish Health Authority. Documentation of National Patient Registries. 2016. https://www.esundhed.dk/Dokumentation (Feb 2023).
2. Varnum C, Pedersen AB, Gundtoft PH, Overgaard S. The what, when and how of orthopaedic registers: An introduction into register-based research. EFORT Open Rev. 2019;4(6):337-43. doi: 10.1302/2058-5241.4.180097.
3. Schmidt M, Schmidt SAJ, Sandegaard JL et al. The Danish National patient registry: a review of content, data quality, and research potential. Clin Epidemiol. 2015;7:449-90. doi: 10.2147/CLEP.S91125.
4. Lynge E, Sandegaard JL, Rebolj M. The Danish national patient register. Scand J Public Health. 2011;39(7 suppl):30-3. doi: 10.1177/1403494811401482.
5. Vest-Hansen B, Riis AH, Christiansen CF. Registration of acute medical hospital admissions in the Danish National Patient Registry: a validation study. Clin Epidemiol. 2013;5:129-33. doi: 10.2147/CLEP.S41905.
6. Pedersen AB, Johnsen SP. [A guide to validate data from clinical quality registries]. Danish. RKKP, 2017. www.rkkp.dk/siteassets/de-kliniske-kvalitetsdatabaser/projekter/valideringmanuel_rkkp_-final_06062017.pdf (Feb 2023).
7. Lass P, Lilholt J, Thomsen L et al. Kvaliteten af diagnose- og procedurekodning i ortopædkirurgi Nordjylland. Ugeskr Læger. 2006;168(48):4212-5.
8. Hjelholt TJ, Edwards NM, Vesterager JD et al. The positive predictive value of hip fracture diagnoses and surgical procedure codes in the danish multidisciplinary hip fracture registry and the danish national patient registry. Clin Epidemiol. 2020;12:123-31. doi: 10.2147/CLEP.S238722.
9. Gadeberg MN, Cramer A, Hölmich P, Barfod KW. Validity of sports-related diagnosis codes in the Danish national patient register. Dan Med J. 2021;68(3):A08200580.
10. Gundtoft PH, Danielsson FB, Houlind M et al. The positive predictive value of ankle fracture diagnosis in the Danish National Patient Registry. Dan Med J. 2022;69(12):A01220032.
11. Bossuyt PM, Reitsma JB, Bruns DE et al. STARD 2015: an updated list of essential items for reporting diagnostic accuracy studies. BMJ. 2015;351:h5527. doi: 10.1136/bmj.h5527.
12. Henriksen DP, Rasmussen L, Hansen MR et al. Comparison of the five Danish regions regarding demographic characteristics, healthcare utilization, and medication use - a descriptive cross-sectional study. PLoS One. 2015;10(10):e0140197 doi: 10.1371/journal.pone.0140197.
13. Statistics Denmark. Population. www.dst.dk/en/Statistik/emner/borgere/befolkning (Feb 2023).
14. Meinberg EG, Agel J, Roberts CS et al. Fracture and dislocation classification compendium – 2018. Orthop Trauma. 2018;32(suppl 1):S1-S170.
15. World Health Organisation. ICD-10: international classification of diseases (10th revision). 2018.
16. The Danish Health Data Authority. Classifications. 2021. https://sundhedsdatastyrelsen.dk/da/english/health_data_and_registers/classifications (Feb 2023).
17. Pedersen CB. The Danish civil registration system. Scand J Public Health. 2011;39(7 suppl):22-5. doi: 10.1177/1403494810387965.
18. Wilson EB. Probable inference, the law of succession, and statistical inference. J Am Stat Assoc. 1927;22(158):209-2. www.med.mcgill.ca/epidemiology/hanley/tmp/proportion/wilson_jasa_1927.pdf (Feb 2023.
19. Stedtfeld HW, Biber R. Proximal third humeral shaft fractures - a fracture entity not fully characterized by conventional AO classification. Injury. 2014;45(suppl 1):S54-S59. doi: 10.1016/j.injury.2013.10.030.