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Upper limb amputations in Germany: a nationwide retrospective study of incidence, aetiologies and revision patterns from 2019 to 2023

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ABSTRACT

Objectives To provide a nationwide epidemiological assessment of upper limb amputations (ULAs) in Germany, including incidence trends, underlying aetiologies, amputation levels and revision patterns, with a comparative analysis between 2019 and 2023.

Design Nationwide retrospective cross-sectional analysis of routinely collected inpatient hospital data.

Setting All acute-care hospitals in Germany reporting to the national Diagnosis-Related Groups and Operation and Procedure Classification System (OPS) from 2019 to 2023.

Participants All patients undergoing ULA procedures (OPS 5-862 and 5-863) or revision procedures (OPS 5-866) within the study period. No exclusion criteria were applied.

Primary and secondary outcome measures Primary measures were annual incidence of ULAs, the distribution of amputation levels and underlying medical aetiologies. Secondary measures included the incidence of revision procedures and revision aetiologies stratified by anatomical level.

Result A total of 5427 ULAs were performed in 2023, representing a 7.3% decrease compared with 2019 (5,852). Distal amputations remained most frequent, though proximal amputations increased proportionally over time. Above-wrist amputations were predominantly associated with malignancy (40.3%) and vascular disease (23.7%), whereas distal amputations were mainly trauma-related (43.6%). Infection-related distal amputations increased from 23.4% in 2019 to 30.4% in 2023. Revision procedures occurred in 32.4% of proximal amputations and 6.1% of distal amputations in 2023. Infection was the most common indication for distal revisions (53.3%), while infection and neuroma formation each accounted for 29.4% of proximal revisions.

Conclusions This nationwide analysis provides a comprehensive epidemiological overview of ULAs in Germany, demonstrating stable overall incidence but clear level-specific differences in underlying aetiologies. Proximal amputations were mainly associated with malignant and vascular disease, whereas trauma predominated at distal levels. High rates of infection-related and neuroma-related revisions, particularly after proximal amputations, highlight the complexity of surgical management and the need for level-specific perioperative and follow-up strategies.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study uses nationwide, routinely collected Diagnosis-Related Group administrative data, which capture all inpatient upper limb amputations performed in Germany.
⇒ Standardised ICD-10 and Operation and Procedure Classification System coding enabled consistent identification of amputation levels and underlying aetiologies.
⇒ The use of administrative data limits clinical detail, including patient comorbidities, mechanisms of injury, perioperative management and functional outcomes.
⇒ Outpatient procedures are not included in the dataset, although such cases represent only a minimal proportion of upper limb amputations.
⇒ Coding accuracy depends on hospital documentation practices and may introduce misclassification or underreporting bias.

INTRODUCTION

Upper limb amputations (ULAs) lead to significant impairments in motor function, sensory perception and bimanual coordination, substantially limiting autonomy, occupational participation and overall quality of life.[1–3] Despite these substantial consequences, comprehensive epidemiological data on ULAs remain limited, particularly at the national level in Europe.

Trauma remains the predominant cause of ULA in younger populations, particularly among those working in high-risk occupations or exposed to motor vehicle accidents.[4 5] Non-traumatic causes, such as vascular diseases, malignancies and infections, are more frequently observed in older individuals.[6] Although malignancy-related

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ULAs are less common, they are critical in cases of advanced or metastatic disease where limb preservation is no longer feasible.[7]

In Norway, a population-based survey estimated the incidence of major ULA at 11.6 per 100 000 adults, with young men disproportionately affected by traumatic, unilateral, distal injuries.[8] Similarly, in Denmark, a national cohort study reported an incidence of upper limb thromboembolectomy of 3.3 per 100 000 person-years for males and 5.2 for females, with subsequent amputation rates of 2.2% and 3.6%, respectively.[5] In France, a retrospective study documented 1715 traumatic ULAs over a 10-year period at Nancy University Hospital, with table saw injuries identified as the leading cause, predominantly affecting middle-aged men.[4]

Existing studies lack comprehensive information on the distribution of amputation levels, underlying diagnoses and revision rates, leaving a significant gap in the understanding of ULAs in European countries. Therefore, the present study aims to assess (1) the incidence of ULAs in Germany, categorised by age, sex and amputation level, (2) the primary medical conditions necessitating amputation, and (3) the frequency and determinants of revision surgeries following ULA.

MATERIALS AND METHODS

This cross-sectional study analysed amputation data from 2019 to 2023, obtained from the German 'Institut für das Entgeltsystem im Krankenhaus'. The dataset comprised annually reported inpatient surgical procedures performed in healthcare facilities across all 16 federal states of Germany, with coding routinely conducted by medical professionals. ULAs were identified using classification codes from the Operation and Procedure Classification System (OPS), specifically the codes '5-862' and '5-863', which encompass interthoracoscapular amputation, shoulder disarticulation, upper arm amputation, elbow disarticulation, forearm amputation, wrist disarticulation, amputation at the carpal level, metacarpal amputation, ray resections and finger amputations (table 1). Revision procedures were classified using the OPS codes '5-866.0' for shoulder or upper arm revisions, '5-866.1' for forearm revisions and '5-866.2' for hand or finger revisions.

A detailed breakdown of the data by diagnosis, age group and sex was conducted for each amputation and revision level, respectively, to provide a comprehensive analysis of trends and patterns in upper extremity amputations.

For the analysis of underlying primary diagnoses in ULAs, cases were categorised into trauma-related causes (ICD-10 codes S42, S48, S58, S68, S63, S62, S65, S61, S66, S64, M84, M87) and infections (ICD-10 codes L02, L03, M00, M65, M72, M86, T81, T79, T84, T87) as the most common indications. Additionally, cases were grouped into vascular disorders including ischaemia and necrosis (ICD-10 codes I70, I73, I74, I77, R02, T87), neoplastic conditions (ICD-10 codes C40, C43, C44, C47, C49, C79, D16), and, for hand amputations, congenital deformities (ICD-10 codes Q68, Q69, Q70), metabolic disorders (ICD-10 codes M10, E11), and other conditions, including degenerative and inflammatory diseases (ICD-10 codes L89, L90, L98, M20, M24, M25, M34, M79, M96, T23, T81, T87). This classification provided a structured framework for assessing the pathological factors leading to amputations in different anatomical regions of the upper extremity.

Data analysis was performed using SPSS V.29.0 (IBM, SPSS). Categorical variables are presented as absolute frequencies and relative proportions. Incidence rates were derived from population data provided by the Federal Statistical Office of Germany (Destatis) for the years 2019 and 2023, considering the demographic distribution across the 16 federal states by birth cohort, with December 31 serving as the reference date for each year. Incidence rate ratios with 95% CIs were estimated to assess relative differences.

Table 1 Classification of procedures and codes for upper limb amputations

Procedure code	Description
5-862.0	Interthoracoscapular amputation
5-862.1	Shoulder disarticulation
5-862.2	Upper arm amputation
5-862.3	Elbow disarticulation
5-862.4	Forearm amputation
5-863.0	Wrist disarticulation
5-863.1	Amputation at the carpal level
5-863.2+5-863.a	Amputation in the metacarpal region
5–863.7+5-8630.8+5-863.9	Hand narrowing by ray resection
5–863.3+5-8630.4+5-863.5+5-863.6	Finger amputation

RESULTS

In 2023, a total of 5427 ULAs were recorded in Germany, representing a 7.3% decrease compared with 2019 (5852 cases). Finger amputations remained the most frequently performed procedure, with 4726 cases and an incidence of 5.58 per 100 000 inhabitants, corresponding to an 8.6% reduction compared with 2019 (5168 cases, 6.21 per 100 000). Amputations at the metacarpal level were documented in 85 cases in 2023, compared with 93 cases in 2019 (-8.6%), while amputations at the carpal level decreased from 13 to 9 cases (–30.8%). In contrast, hand-narrowing procedures by ray resection remained largely unchanged (344 vs 345 cases). Wrist disarticulations were recorded in 25 cases in 2023, corresponding to an incidence of 0.03 per 100 000 inhabitants, compared with 16 cases in 2019 (0.02 per 100,000) (+56.2%) (table 2, figure 1b).

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Table 2 Incidence rates of specific upper limb amputation procedures in 2023 compared with 2019

Procedure	Total numbers 2023	Total numbers 2019	Incidence per 100 000 (2023)	Incidence per 100 000 (2019)	Relative change (%)	Incidence rate ratio (95% CI)
Interthoracoscapular amputation	14	12	0.02	0.01	16.7	2.0 (1.18 to 3.38)
Shoulder disarticulation	19	24	0.02	0.03	–20.8	0.67 (0.43 to 1.05)
Upper arm amputation	98	86	0.12	0.1	14.0	1.2 (0.98 to 1.46)
Elbow disarticulation	11	9	0.01	0.01	22.2	1.0 (0.55 to 1.81)
Forearm amputation	96	86	0.11	0.1	11.6	1.1 (0.9 to 1.34)
Wrist disarticulation	25	16	0.03	0.02	56.2	1.5 (1.01 to 2.22)
Amputation at the carpal level	9	13	0.01	0.02	–30.8	0.5 (0.26 to 0.96)
Amputation at the metacarpal level	85	93	0.1	0.11	–8.6	0.91 (0.74 to 1.13)
Hand narrowing by ray resection	344	345	0.41	0.41	–0.3	1.0 (0.9 to 1.11)
Finger amputation	4726	5168	5.58	6.21	–8.6	0.9 (0.87 to 0.93)

Amputations at the proximal levels exhibited varying trends. The number of interthoracoscapular amputations increased from 12 to 14 cases, with an incidence of 0.02 per 100 000 inhabitants in 2023. Upper arm amputations were reported in 98 cases (0.12 per 100 000), compared with 86 cases in 2019 (0.10 per 100 000) (+14.0%). Shoulder disarticulations declined from 24 cases (0.03 per 100 000) in 2019 to 19 cases (0.02 per 100 000) in 2023 (–20.8%). The number of forearm amputations increased from 86 cases in 2019 to 96 cases in 2023, with an incidence of 0.11 per 100 000 inhabitants (table 2, figure 1a).

The analysis of gender distribution reveals a consistent predominance of male patients in both amputation groups, though with a relative increase in female patients over the years. In above-wrist amputations, the proportion of male patients decreased from 60.19% in 2019 to 55.60% in 2023, while the female proportion increased to 44.40%. The gender difference was even more pronounced in below-wrist amputations, where the male proportion declined from 74.30% to 70.31%, and the female proportion rose to 29.69%.

The age distribution indicates a shift towards older patient groups. In above-wrist amputations, the 65–74 age group accounted for the highest proportion in 2023 (25%), followed by the 30–39 and 40–49 age groups (each 10.3%). Compared with 2019, the proportion of patients aged 65–74 increased, while the share of those aged 75–79 decreased. In below-wrist amputations, the 80+ age group had the highest proportion (20.2%), followed by the 65–74 group (19.8%). The data show an increase in older patients, particularly those over 80, suggesting that vascular conditions, diabetes and falls may play a role in the incidence of upper extremity amputations (figure 2).

The distribution of aetiologies for above-wrist amputations in 2023 is presented in figure 3a. Malignancy was the most common indication, representing 40.3% of cases, though its share decreased from 54.8% in 2019. Vascular-related amputations were the second most frequent cause, accounting for 23.7%, with a minor increase compared

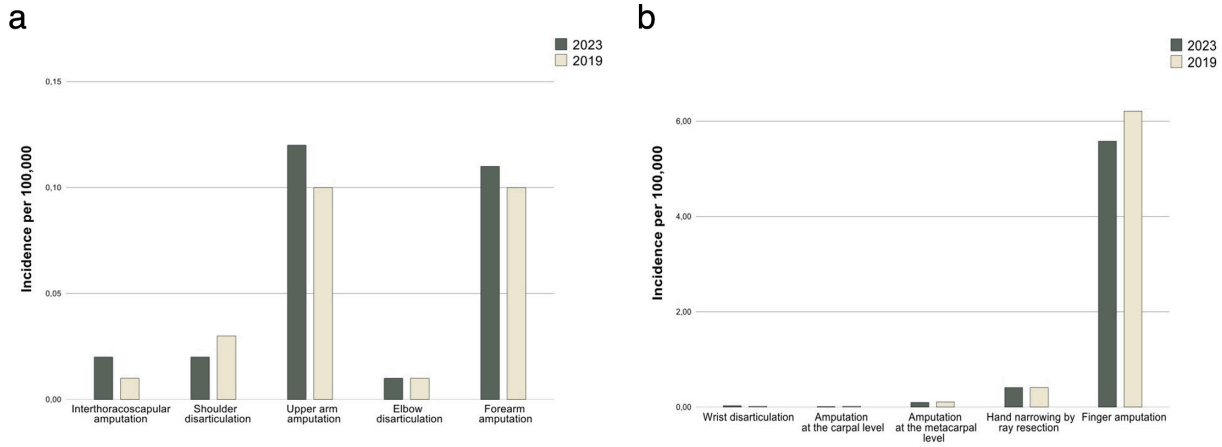


Figure 1 Incidence of upper limb amputations per 100 000 population in Germany (2019 vs 2023). (a) above-wrist amputations, (b) below-wrist amputations. Dark bars: 2023; light bars: 2019.

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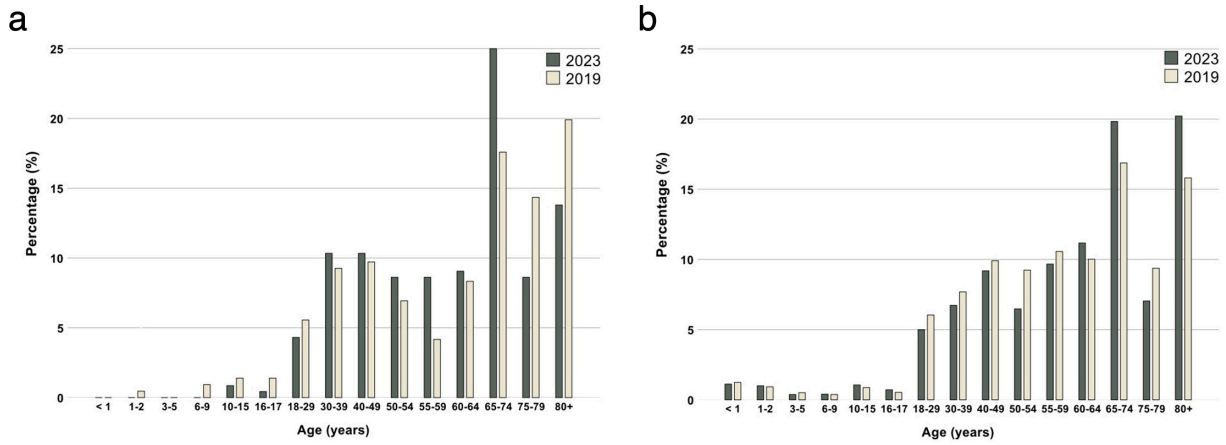


Figure 2 Age distribution of upper limb amputations in Germany (2019 vs 2023). (a) above-wrist amputations, (b) below-wrist amputations. Dark bars: 2023; light bars: 2019.

with 2019. Trauma comprised 21.1% of cases, nearly doubling in comparison to 2019 (10.7%), while infection-related cases remained at a comparable level (14.9%).

A more detailed evaluation showed that neoplastic amputations were primarily associated with malignant tumours of bone, soft tissues or skin. Vascular and ischaemic cases were mainly attributable to peripheral arterial disease, gangrene or thromboembolic events of the upper extremity. Trauma-related proximal amputations consisted predominantly of high-level traumatic amputations involving the region between the shoulder and elbow, and wrist, as well as humeral shaft fractures requiring secondary amputation. Infectious proximal amputations were largely due to necrotising fasciitis involving the upper arm or forearm.

The distribution of underlying causes for below-wrist amputations in 2023 is shown in figure 3a. Trauma remained the most frequent aetiology, accounting for 43.6% of cases, though its proportion declined compared with 2019 (51.5%). In contrast, infection-related indications increased to 30.4%, exceeding the proportion observed in 2019 (23.4%). Vascular origins were identified in 12.5% of cases, showing a slight rise. Malignancy accounted for 3.3%, with no substantial change from 2019, while the proportion of cases attributed to other causes remained largely stable.

Further analysis revealed that the trauma subgroup consisted mainly of traumatic complete or partial digit amputations and multiple finger injuries, followed by fractures and soft-tissue trauma. Infectious causes included osteomyelitis of the hand and digits, phlegmonous infections, tenosynovitis and wound infections. Vascular and ischaemic indications in distal amputations were primarily associated with gangrene, critical limb ischaemia, diabetic vascular complications, thrombosis and Raynaud-associated ischaemia. Degenerative and other disorders comprised chronic joint disease, contractures, Dupuytren's disease, neuromas and other chronic structural pathologies. Congenital deformities represented the smallest aetiologic group (<2%). Within this category, duplication anomalies constituted the majority (81.6% in 2019 and 86.3% in 2023), followed by syndactyly (5.7% in

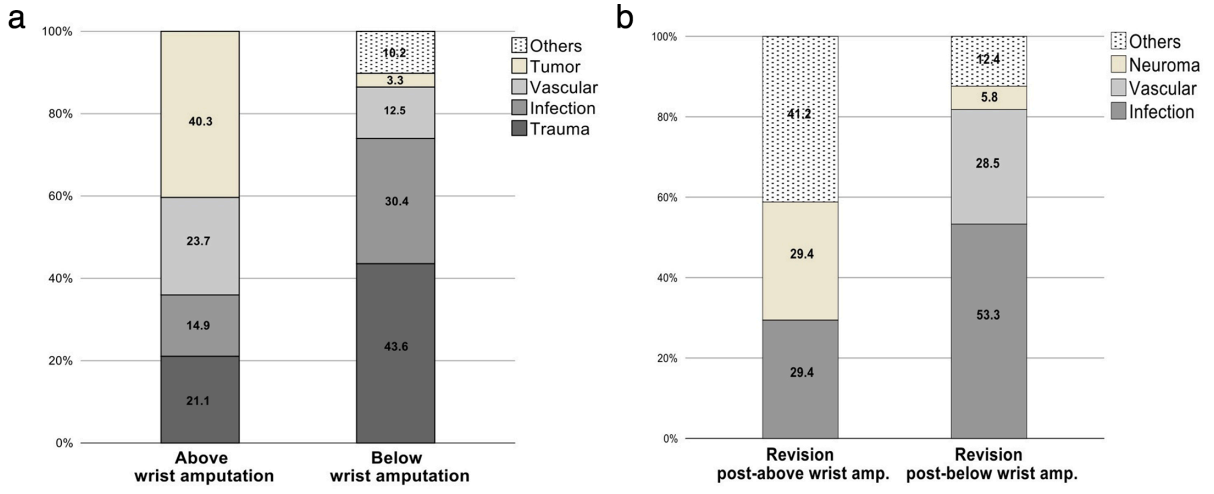


Figure 3 Aetiology and revision indications in upper limb amputations. (a) causes of above-wrist and below-wrist amputations, (b) reasons for revision surgery following above-wrist and below-wrist amputations.

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Table 3 Incidence rates of revision amputation procedures divided by anatomical localisation

Anatomical localisation	Total revisions 2023	Total revisions 2019	Revision rate 2023 (%)	Revision rate 2019 (%)	Relative change (%)	Percentage female/Male 2023	Most affected age group (%) 2023
Hand	319	330	6.1%	5.8%	+4.8%	24/76	65–74 years (21.6%)
Forearm, upper arm and shoulder	77	79	32.4%	36.4%	–11.1%	28/72	40–49 years (18.4%)

2019, 13.7% in 2023), while other congenital causes were not recorded in 2023.

A more detailed analysis of amputation levels reveals distinct patterns of underlying causes in 2023. In cases of thoracoscapular amputation and shoulder disarticulation, the indication was exclusively neoplastic, with soft tissue tumours being more prevalent than primary bone tumours and malignant cartilage tumours. For upper arm amputations, trauma was the leading cause, followed by malignant diseases. In contrast, vascular pathology was the predominant aetiology in forearm amputations. Proximal hand amputations were most frequently performed due to vascular causes, whereas trauma was the predominant indication for finger amputations. Regarding ray resections, infection was the most common indication for resection of the second, third and fourth rays. Notably, in resections of the fifth ray, Dupuytren's disease was the most frequently identified cause.

In 2023, a total of 319 revisions following amputations were performed in the hand region and 77 in the proximal upper extremity. Compared to 2019, with 330 and 79 cases respectively, the revision rate in the hand region increased from 5.8% to 6.1%, while it decreased in the proximal region from 36.4% to 32.4% (table 3).

Men were more frequently affected in both regions in 2023, accounting for 76% of cases in the hand region and 72% in the proximal area. The most commonly affected age group in the hand region was 65–74 years (21.6%), whereas in the proximal region, individuals aged 40 to 49 years (18.4%) were most frequently affected.

The causes of revision varied depending on the level of amputation (figure 3b). After distal amputations, infection was the most common cause at 53.3%, followed by vascular complications (28.5%) and neuromas (5.8%). Following proximal amputations, infections and neuromas each accounted for 29.4% of cases.

DISCUSSION

The present analysis highlights distinct epidemiological patterns in ULAs across Germany. While finger amputations remain most frequent, their incidence declined notably, contrasting with a relative increase in proximal amputations, especially among older adults. This shift reflects demographic ageing and the rising burden of vascular and malignant conditions. Notably, trauma continues to dominate as the leading indication in distal amputations, whereas oncologic and ischaemic causes predominate proximally. Revision rates varied considerably by amputation level, underscoring the need for differentiated perioperative and rehabilitative approaches.

Incidence of ULAs in Germany, categorised by age, sex and amputation level

ULAs remain significantly less frequent than Lower Limb amputations (LLAs), a trend observed worldwide.[9 10] In Germany, ULAs constituted a small fraction of total amputations, consistent with findings from the USA, where ULAs accounted for only 9.2% of all limb loss cases in 2019.[11] The incidence of ULAs in Germany remained stable from 2019 to 2023, with a slight decline in finger amputations. In contrast, a Korean study based on national disability registration data from 2011 to 2020 showed a long-term decline in ULAs, likely related to improvements in occupational safety regulations, stricter enforcement and increased use of protective equipment in high-risk industries, while LLAs increased, driven by rising diabetes prevalence.[12]

Our results confirm a predominant male distribution, consistent with international data showing that trauma-related ULAs are significantly more common in men, likely due to higher occupational and accident-related exposure.[13 14] A significant proportion of ULAs occurs in elderly patients, particularly those aged 65–74, a trend observed both in our data and in European and Asian studies. While studies from South Korea report an increasing incidence among older workers,[15] research from the USA[16] and Europe[4] likewise highlights the high prevalence of ULAs in this age group.

Medical conditions necessitating amputation

The aetiological spectrum identified in this national dataset indicates that ULAs in Germany arise from a broader range of clinical conditions than traditionally emphasised in global epidemiology. While trauma is widely described as a leading worldwide cause—particularly in settings with substantial exposure to machinery injuries, traffic accidents or humanitarian crises[14 17 18]—the pattern observed in Germany reflects a more differentiated distribution. Distal amputations are more frequently associated with traumatic mechanisms, whereas proximal amputations are predominantly linked to malignant and vascular processes. This contrasts with LLAs, where vasculopathic disease is the principal indication across all levels.[19]

Within this context, the prominence of non-traumatic aetiologies in major ULAs aligns with observations from high-income healthcare systems, where oncologic, vascular and complex infectious conditions increasingly

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shape surgical decision-making.[20] The relevance of malignant tumours reflects clinical situations in which oncologic clearance remains necessary despite advances in limb-preserving techniques.[21 22] Vascular indications correspond to the recognised role of upper extremity ischaemia in multimorbid or elderly populations.[23] Infectious causes—particularly rapidly progressive soft-tissue and bone infections—remain clinically significant and are consistent with reports highlighting the susceptibility of the upper limb to aggressive infectious spread.[24 25] Congenital deformities were observed only in isolated cases and reflect the uncommon situations in which persistent or functionally significant anomalies may still require operative management, including selective amputation.[26 27] Among the less frequent aetiologies, advanced degenerative conditions, recalcitrant neuromas, fixed contractures and fibroproliferative disorders represent clinical constellations that have been described as rare but relevant pathways toward ULAs. These situations typically arise when prolonged structural or functional impairment leaves no viable reconstructive options, rendering a limited amputation an accepted definitive intervention.[28 29]

Frequency and determinants of revision surgeries following ULA

Revision rates for ULAs demonstrated divergent trends depending on the anatomical level. While the revision rate for hand amputations showed a slight increase from 5.8% in 2019 to 6.1% in 2023, proximal ULAs exhibited a decline in revision surgeries from 36.4% to 32.4%. Men were more frequently affected in both anatomical levels, likely due to the predominance of traumatic ULAs in this population. These cases often involve high-energy mechanisms, such as blast injuries or industrial accidents, which can result in complex residual limb complications necessitating revision surgeries.[18 30]

In our cohort, infection was the most common indication for distal revisions (53.3%), whereas in proximal amputations, infection and neuroma were equally prevalent (29.4% each). These findings are consistent with previous studies identifying infection and symptomatic neuromas as the leading causes of revision procedures following ULAs.[31 32] Advancements in surgical techniques and improved postoperative care appear to have contributed to the overall decline in revision rates. Techniques such as targeted muscle reinnervation have shown particular promise in managing neuroma-related pain and enhancing prosthetic function, thereby reducing the need for secondary interventions.[33] Furthermore, comprehensive postoperative care, including early prosthetic fitting and coordinated, multidisciplinary rehabilitation, has played a pivotal role in optimising functional outcomes and minimising complications.[14]

The variation in revision trends observed in our study underscores the importance of level-specific considerations in both surgical planning and postoperative follow-up. These outcomes are influenced by multiple factors that need to be identified and addressed individually.[34 35]

Limitations

Registry-based analyses inherently lack detailed clinical information, and the nationwide DRG/OPS dataset used in this study is no exception. While principal diagnoses and procedural codes are available, the dataset does not provide temporal information such as the interval between primary amputation and revision surgery, nor does it include perioperative or postoperative rehabilitation details. As a result, time-dependent analyses and the evaluation of rehabilitation pathways are not possible. In addition, the dataset contains no patient-level variables or linkable identifiers, which prevents multivariable analyses or the assessment of individual risk factors. Geographic markers that would allow urban–rural stratification or broader geographic comparisons are also not included in the publicly accessible data. Direct attribution of amputations to specific aetiologies must be interpreted with caution, as administrative coding may not reflect the full clinical context. Standardised coding definitions are essential for international comparability.[36 37] The use of OPS codes in this study provides a high degree of specificity in classifying ULA levels and addresses limitations that may arise from DRG-based coding. Although coding inaccuracies or upcoding cannot be entirely excluded, the strict regulation and auditing of DRG reimbursement by the German Medical Service support a high level of reliability.[19] Despite these inherent limitations, the dataset enables a robust national representation of inpatient ULAs and allows the identification of meaningful epidemiological trends at the population level.

CONCLUSIONS

This study provides the first nationwide, longitudinal analysis of ULAs in Germany, offering an epidemiological framework that was previously unavailable and enabling more informed healthcare planning. While overall ULA numbers showed only minor fluctuations, proximal amputations—largely driven by malignancies and vascular disease—remained a substantial clinical burden, whereas trauma continued to predominate at distal levels. The notably high proportion of infection- and neuroma-related revision procedures, particularly following proximal ULAs, underscores the complexity of surgical management and the need for level-specific perioperative concepts, neuroma-preventive techniques and structured postoperative follow-up pathways.

The clinical relevance of these findings lies in their implications for surgical decision-making, early complication detection and targeted long-term care. To advance the field, future research should integrate patient-level data, functional outcome measures, prosthetic utilisation patterns and structured rehabilitation assessments. Establishing dedicated registries and conducting prospective studies will be essential to refine care pathways, reduce

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revision risks and improve long-term outcomes for individuals undergoing ULA.

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Contributors BA and MR conceived and designed the study. BA performed data extraction, data processing, statistical analysis and prepared all figures and tables. BA drafted the initial manuscript. MR supervised the study, contributed to data interpretation and revised the manuscript. All coauthors critically reviewed and revised the manuscript for important intellectual content. All authors approved the final manuscript and agree to be accountable for all aspects of the work. MR is the guarantor of the study and accepts full responsibility for the integrity of the work and the decision to submit the manuscript for publication. AI technology (ChatGPT by OpenAI) was used solely for language editing and grammar correction. The content, structure and scientific interpretation were created entirely by the authors.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This observational study was conducted in accordance with the ethical principles of the 1964 Declaration of Helsinki. As mandated by the German Social Code (SGB V §21), nationwide DRG/OPS hospital data are provided in irreversibly anonymised form for scientific use; therefore, studies using these data do not require ethics approval under German or EU regulations. This was confirmed by the local ethics committee of the University of Giessen.

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Data availability statement Data are available on reasonable request. The datasets analysed during the current study are available from the corresponding author on reasonable request.

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