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## Original Article

# Major traumatic amputations and replantations of the upper extremity in Germany – National quality reports 2014–2018

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## ABSTRACT

The treatment of traumatic major upper limb amputation is complex and of great urgency. Loss of time often represents a major restriction for replantation. Thus, logistical and infrastructural developments, such as the expansion of specialised hand trauma centres, are crucial for optimizing delivery of care. Surveillance represents the fundament for a proper, demand-adapted implementation of such therapeutical improvements. However, a comprehensive database for surveillance of these injuries does currently not exist in Germany or Europe.

In this study quality reports of German hospitals from 2014 to 2018 were screened retrospectively for traumatic major upper extremity amputations and replantations. A total of 329 amputations and 87 replantations were recorded, accounting for an overall replantation rate (RR) of 26%. Most of the injuries affected the level of the wrist and forearm. Treatment of these injuries experienced an increasing centralisation to medical teaching facilities, which accounted for higher RRs compared with non-teaching facilities. The cumulatively most populous federal states handled most of the amputation injures in this five-year study period.

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Ratio calculations on the basis of population counts, however, revealed great discrepancies to these results, with Hamburg, Rhineland-Palatinate and Saarland accounting for the highest per capita incidences. In 2018 Germany was provided with 46 specialised hand trauma and replantation centres, which performed 45% of the replantations in that year, revealing a RR of 17%, compared to an overall RR of 14% in that year. Nevertheless, there might be potential for improvement in the geographical distribution of these specialised centres.

The provision of highly specialised therapy in highly specialised centres for highly complex injuries is a future challenge in replantation surgery. This data is contributing to logistical improvements for a need-adapted expansion of these specialised hand trauma centres.

The study demonstrates an approach of a standardised and comprehensive injury surveillance program based on national quality reports, while underlining the importance of such a national or rather European database for optimisations in medical care.

Level of evidence IV.

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## Introduction

Trauma still represents the most common cause for upper extremity loss with an estimated 83%.<sup>1</sup> This is in contrast to lower limb amputations, where the majority is caused by peripheral vascular disease. In the year 2005, an estimated number of 500.000 Americans were living with minor amputations and 43.000 with major amputations of the upper extremity,<sup>1</sup> accompanied by grave functional and aesthetical impairments for the amputees. Since the 1970s limb replantation techniques and replantation outcomes have improved markedly. According to the US State Inpatient Database of the Healthcare Cost and Utilisation Project, of a total of 9.407 upper limb amputations counted in the years 2001, 2004 and 2007, 1.361 received replantation.<sup>2</sup> Data shows that replantation rates (RRs) in the USA are clearly related to the type of the treating institution, accounting for higher RRs in major, teaching, and urban hospitals.<sup>2,3</sup>

Technical difficulty, extensive surgery time and postoperative care as well as high probability for surgical revisions make major upper extremity replantations complex and risky procedures, coupled with substantial financial expenses.<sup>2,3</sup> Nevertheless, successful replantation represents probably the ideal therapy for amputees, in terms of esthetical and functional reconstruction. The condition of the amputee and the limb often remain immutable major obstacles to successful replantation. Logistical, infrastructural or surgical aspects, in terms of shortened ischemia times and optimised surgical care, however, can be influenced and may equally affect replantation success and outcome. As a consequence, specialised replantation centres have been established over the last years, and are still developing, to ensure optimal treatment conditions. In Europe, the Hand Trauma Committee of the Federation of European Societies for Surgery of the Hand (FESSH) has defined clear accreditation criteria to provide quality assured hand trauma care throughout the continent.<sup>4</sup>

Although, many trauma centres have recently been established in Germany, their current demand-effective regional supply remains uninvestigated up to now. Major upper limb amputation injuries probably represent the most complex trauma type treated in these specialised hand trauma centres, but are not yet comprehensively recorded by a German national or rather international trauma registry in Europe.

**Table 1**  
ICD-10-GM codification for major traumatic upper extremity amputations.

ICD-10 GM Code	Level of amputation	2014	2015	2016	2017	2018
S48.0	Traumatic amputation at the level of the shoulder joint	3 (4%)	3 (4%)	0 (0%)	5 (10%)	5 (8%)
S48.1	Traumatic amputation between shoulder and elbow	15 (19%)	17 (25%)	18 (27%)	13 (25%)	20 (31%)
S48.9	Traumatic amputation at the level of shoulder and upper arm, height not further specified	4 (5%)	4 (6%)	2 (3%)	1 (2%)	1 (2%)
S58.0	Traumatic amputation at the level of the cubital joint	0 (0%)	5 (7%)	7 (10%)	3 (6%)	5 (8%)
S58.1	Traumatic amputation between elbow and wrist	27 (35%)	18 (26%)	13 (19%)	14 (27%)	12 (19%)
S58.9	Traumatic amputation of the forearm, height not further specified	3 (4%)	4 (6%)	3 (4%)	1 (2%)	2 (3%)
S68.4	Traumatic amputation of the hand at level of the wrist	25 (32%)	16 (24%)	22 (33%)	14 (27%)	19 (30%)
S68.8	Traumatic amputation of other parts of the wrist and hand	1 (1%)	1 (1%)	2 (3%)	1 (2%)	0 (0%)
Total		78 (100%)	68 (100%)	67 (100%)	52 (100%)	64 (100%)

Absolute and relative numbers of the recorded ICD-10-GM codes in Germany for the years 2014–2018.

In Germany, the Hand Trauma Register of the German Society of Hand Surgery (DGH), started in 2018, counts 31 voluntarily participating departments.<sup>5</sup> The Trauma Register of the German Trauma Society (TR-DGU), comprising European as well as non-European nations, such as Germany, Austria, Switzerland, Netherlands, Belgium, Slovenia, Luxembourg, Finland and the United Arab Emirates, reported 321 macroamputations and 76 macroreplantations of the upper extremity within the years 1993–2010.<sup>6</sup> However, the TR-DGU exclusively records trauma patients requiring intensive care or treatment in an intermediate care unit, admitted to one of the voluntarily participating trauma hospitals.

The purpose of this study was to provide a role model of comprehensive surveillance of major upper limb amputations and replantations, with regard to their regional distribution, level of injury and the type of treating medical institution, exemplified by the quality reports of German hospitals, in order to identify opportunities for infrastructural improvement of medical care.

## Materials and methods

This study was designed as a retrospective national multicentre analysis. Ethical approval to report these data was waived by the Ethics Committee of the Hannover Medical School. Quality reports, made available by the national federal committee of German hospitals for the years 2014–2018, were screened for major upper extremity amputation injuries (defined as amputations at the level of or proximal to the wrist) as well as their replantations. Since 2014, all German hospitals are legally required to deliver annual quality reports about their work and structures, including diagnoses, treatment spectrum, treatment frequencies, staffing, and the like. These data reports originate from hospital invoicing data exclusively and do not provide any demographic information about patients.

Data extraction was accomplished by usage of the ICD-10-GM (International Statistical Classification of Diseases and Related Health Problems 10th Revision German Modification) codes S48.0, S48.1, S48.9, S58.0, S58.1, S58.9, S68.4 (Table 1) and the OPS (Operation and Procedure Classification System) codes 5–860, 5–860.0, 5–860.1, 5–860.2, 5–860.3 (Table 2).

The number of distinct OPS codes recorded within the individual medical institutions per year was not specified in the quality reports if it was below four. None of the included institution exceeded this cut-off with regard to replantations. Considering that major upper limb amputations are relatively rare injuries, the number one, as the smallest possible number, was assumed in these cases of lacking specification.

**Table 2**  
OPS codification for major upper extremity replantations.

OPS Code	Level of replantation	2014	2015	2016	2017	2018
5–860.0	Replantation at the level of the upper arm	5 (22%)	2 (11%)	2 (12%)	4 (20%)	1 (11%)
5–860.1	Replantation at the level of the elbow	2 (9%)	1 (6%)	0 (0%)	2 (10%)	0 (0%)
5–860.2	Replantation at the level of the forearm	8 (35%)	7 (39%)	7 (41%)	5 (25%)	2 (22%)
5–860.3	Replantation at the level of the wrist	8 (35%)	8 (44%)	8 (47%)	9 (45%)	6 (67%)
Total	Replantation of the upper extremity	23 (100%)	18 (100%)	17 (100%)	20 (100%)	9 (100%)

Absolute and relative numbers of recorded OPS codes in Germany for the years 2014–2018.

The obtained data set of German quality reports was further analysed for plausibility. Thenceforth, all OPS codes for major extremity replantation without a correlating ICD-10-GM code from the same institution within the investigated years were excluded from the analysis, as an underlying coding error has been assumed. In addition, ICD-10-GM codes which were recorded repeatedly within different departments of the same institution (e.g. department for trauma surgery, department of hand or plastic surgery, department of anaesthesiology or intensive care medicine) were counted only once. In these cases, a multiple-coding, associated with the multidisciplinary treatment modality of these injuries, has to be presumed. The ICD-10-GM codes S68.8 (Traumatic amputation of other parts of the wrist and hand) and S68.9 (Traumatic amputation of the wrist and hand, height not further specified) comprise amputations of the hand and wrist and can thus, not be counted as major amputation injury exclusively. To prevent the false inclusion of more distally localised amputation injuries, these ICD-10-GM codes were excluded from the data analysis, accepting a probable loss of wrist amputation counts. If, however, there was a corresponding S68.8 or S68.9 diagnosis to a recorded wrist replantation (5–860.3) in the same institution within the same year this code was selectively included as wrist amputation injury in the analysis. Institutions such as rehabilitation centres, which coded these items, but are very unlikely to have performed these procedures, were excluded from the analysis as well.

Furthermore, teaching assignments of the single institutions as well as their affiliation to Germany's 16 federal states were analysed. In addition, data about the FESSH-accredited hand trauma and replantation centres (HTRCs) in Germany in the year 2018 were included in our analyses. These data were kindly provided by the FESSH itself. Demographic data published by the German statistic department of the federation and the federal states for the year 2014, 2015, 2016, 2017 and 2018<sup>7</sup> were used to calculate population-based incidences of major amputation of the upper limb in all German federal states.

## Results

After an accurate data verification process, a total of 329 major amputation injuries and 87 replantations were included in this study (Tables 1, 2, S1 and S2). These numbers account for an overall RR of 26% for the observed five-year time period in Germany (Table 3). Information about patients' age or sex was not available, as quality reports do not include demographic data. None of the aforementioned centres performed more than four major upper extremity replantations at the same level in one of the reviewed years.

### Level of amputation

The majority of amputations affected the wrist and forearm ( $n = 198$ , 60%), while the most frequent ICD-10-GM codes were S68.4 (Traumatic amputations of the hand at level of the wrist;  $n = 96$ , 29%), S58.1 (Traumatic amputations between elbow and wrist;  $n = 84$ , 26%), and S48.1 (Traumatic amputations between shoulder and elbow;  $n = 83$ , 25%) (Table 1). Replantations, too, were performed most frequently at the level of the wrist and forearm. The leading OPS codes were 5–860.3 (Replantation at the level of the wrist;  $n = 39$ , 45%) and 5–860.2 (Replantation at the level of the forearm;  $n = 29$ , 33%) (Table 2). With 38% RR was highest in the year 2017, while it hit the rock bottom with 14% in 2018 (Table 3).

**Table 3**

Numbers of major traumatic amputations and replantations (absolute and relative numbers) as well as replantation rates (RRs) according to teaching assignments of the treating medical institutions, in the years 2014–2018 in Germany.

	2014	2015	2016	2017	2018	Total
Amputations <i>n</i> (%)	78 (100%)	68 (100%)	67 (100%)	52 (100%)	64 (100%)	329 (100%)
Non-teaching facility	5 (6%)	4 (6%)	0 (0%)	0 (0%)	1 (2%)	10 (3%)
Teaching facility	73 (94%)	64 (94%)	67 (100%)	52 (100%)	63 (98%)	319 (97%)
Teaching facility <i>n</i> (%)						
University hospital	17 (22%)	21 (31%)	27 (40%)	22 (42%)	22 (35%)	109 (34%)
Academic educational hospital	56 (72%)	43 (63%)	40 (60%)	30 (58%)	41 (65%)	210 (66%)
Replantations <i>n</i> (%)	23 (100%)	18 (100%)	17 (100%)	20 (100%)	9 (100%)	87 (100%)
Non-teaching facility	1 (4%)	1 (6%)	0 (0%)	0 (0%)	0 (0%)	2 (2%)
Teaching facility	22 (96%)	17 (94%)	17 (100%)	20 (100%)	9 (100%)	85 (98%)
Teaching facility <i>n</i> (%)						
University hospital	8 (35%)	6 (33%)	6 (35%)	11 (55%)	2 (22%)	33 (39%)
Academic educational hospital	14 (61%)	11 (61%)	11 (65%)	9 (45%)	7 (78%)	52 (61%)
Replantation Rate RR (%)	29%	26%	25%	38%	14%	26%
RR University hospitals	47%	29%	22%	50%	9%	30%
RR Academic educational hospital	25%	26%	28%	30%	17%	25%
RR Non-teaching facility	20%	25%	0%	0%	0%	20%
RR Teaching facility	30%	27%	25%	38%	14%	27%

### Teaching assignment

There was a notable shift in treatment of the recorded amputation injuries towards teaching hospitals. While 6% of the major upper limb amputations were still treated in non-academic institutions in the years 2014 and 2015, only one of the recorded injuries was treated in a medical institution without teaching assignment in the period 2016–2018. Overall educational institutions accounted for higher RRs compared with non-teaching facilities (Table 3).

### Population geography

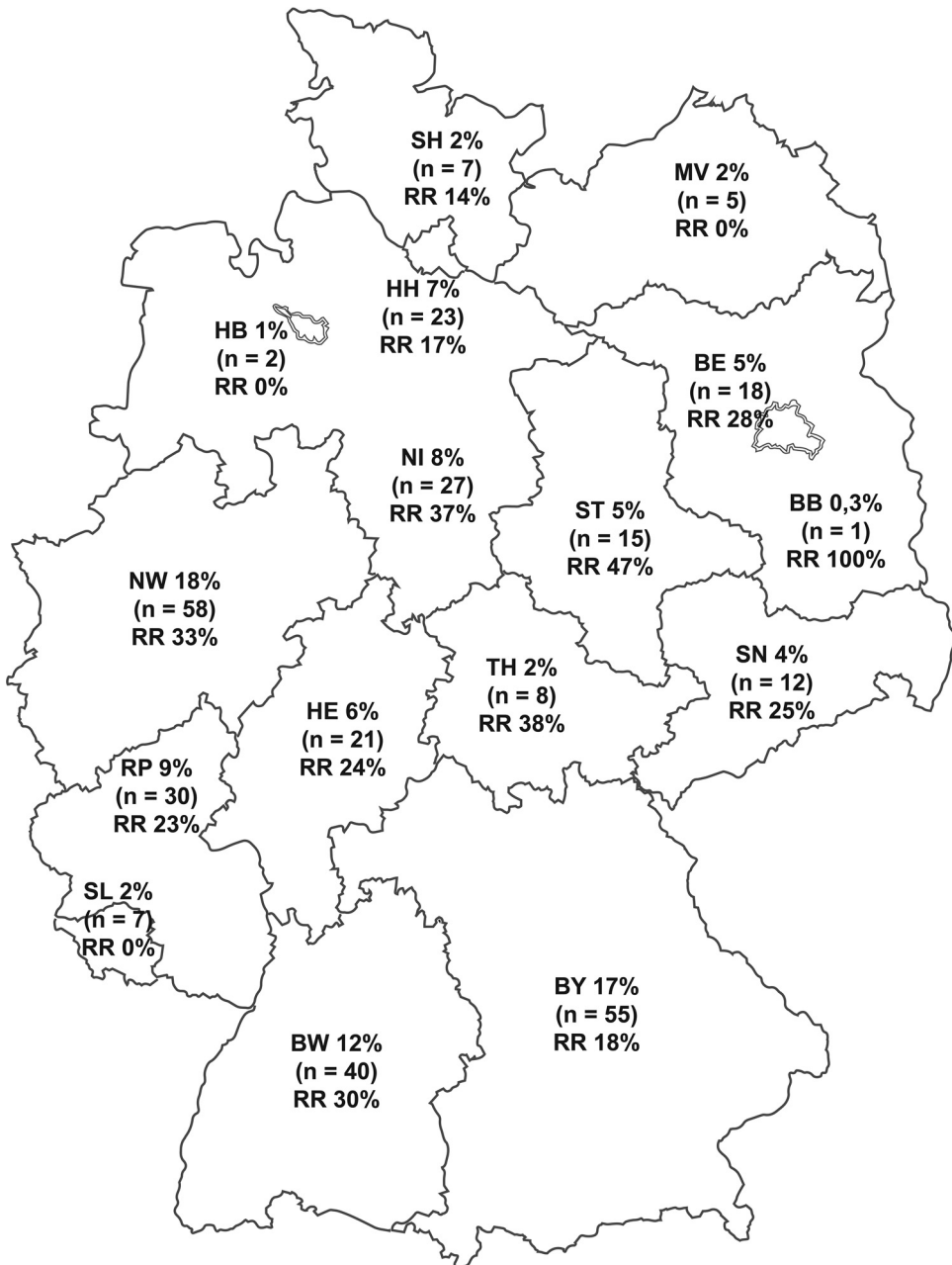
The overall most populated German federal states are North Rhine-Westphalia (NW), Bavaria (BY), Baden-Württemberg (BW), which handled most of the recorded amputation injuries (NW *n* = 58, 18%; BY *n* = 55, 17%; BW *n* = 40, 12%). These three federal states plus Lower Saxony recorded most major upper extremity replantations between 2014 and 2018 (NW *n* = 19, 22%; BW *n* = 12, 14%; BY *n* = 10, 11%; NI *n* = 10, 11%) (Fig. 1). The highest RRs were identified in Saxony-Anhalt (RR 47%), Thuringia (RR 38%) and Lower Saxony (RR 37%) (Brandenburg with a single amputation only was excluded from this ranking, despite its RR of 100%).

Considering the population counts of the German federal states in the analysis disclosed that Hamburg (HH) had the highest overall emergence of amputations per habitants in this five-year study period, followed by Rhineland-Palatinate (RP) and Saarland (SL) (HH 2.57, RP 1.49 and SL 1.41 amputations per one million habitants). Data for the individual years is listed in Table 4.

### Hand trauma and replantation centres (HTRCs)

Overall there were 46 FESSH-accredited HTRCs in Germany in the year 2018, most of them were located in Bavaria, Baden-Württemberg, North Rhine-Westphalia and Lower Saxony (NI) (BY *n* = 11, 24%; BW *n* = 8, 17%; NW *n* = 7, 15%; NI *n* = 7, 15%) (Fig. 2).

Analyses of HTRCs per number of habitants revealed that Bremen (HB), Hamburg and Saxony-Anhalt (ST) held the greatest population-related density of HTRCs (HB 2.94, HH 1.09 and ST 0.9 HTRCs per one million habitants) 2018 in Germany. The federal states lacking a HTRC were Brandenburg, Saarland, Saxony and Thuringia. Forty-five percent (*n* = 29) of the recorded amputations were treated in HTRCs, while 56% (*n* = 5) of the replantations were conducted in HTRCs. This accounts for an overall RR of 17% in FESSH-accredited HTRCs in the year 2018 (Table 5).



**Fig. 1.** National distribution of major traumatic upper extremity amputations as well as replantation rates (RRs) in Germany, by federal states, within the years 2014–2018. Relative (100%) and absolute amputation counts ( $n = 329$ ) as well as RRs (26%) related to the German federal states within 2014–2018. Baden-Württemberg (BW), Bavaria (BY), Berlin (BE), Brandenburg (BB), Bremen (HB), Hamburg (HH), Hesse (HE), Lower Saxony (NI), Mecklenburg-West Pomerania (MV), North Rhine-Westphalia (NW), Rhineland-Palatinate (RP), Saarland (SL), Saxony (SN), Saxony-Anhalt (ST), Schleswig-Holstein (SH), Thuringia (TH).

**Table 4**

Population-based counts as well as regional replantation rates (RRs) in the years 2014–2018, assigned to the German federal states.

2014	Habitants (k)	Amputations	Amputations/Habitants (m)	RR (%)
HB	659,6	1	1,52	0
SL	989,9	0	0	0
MV	1.597,80	1	0,63	0
HH	1.754,60	8	4,56	0
TH	2.158,80	3	1,39	33
ST	2.240,10	2	0,89	50
BB	2.453,50	0	0	0
SH	2.823,40	3	1,06	0
BE	3.445,80	3	0,87	67
RP	4.003,00	13	3,25	8
SN	4.050,80	6	1,48	17
HE	6.069,70	4	0,66	75
NI	7.808,60	2	0,26	50
BW	10.674,00	10	0,94	30
BY	12.647,90	10	0,79	30
NW	17.605,00	12	0,68	58
G total	80.982,50	78	0,96	29
2015	Habitants (k)	Amputations	Amputations/ Habitants (m)	RR (%)
HB	666,7	1	1,50	0
SL	992,3	2	2,02	0
MV	1.605,80	1	0,62	0
HH	1.775,10	3	1,69	0
TH	2.163,70	1	0,46	100
ST	2.240,50	3	1,34	67
BB	2.471,30	0	0	0
SH	2.844,80	2	0,70	0
BE	3.494,90	5	1,43	20
RP	4.032,20	2	0,50	0
SN	4.070,10	1	0,25	0
HE	6.135,00	4	0,65	25
NI	7.876,70	7	0,89	57
BW	10.798,10	12	1,11	25
BY	12.767,50	14	1,10	29
NW	17.751,80	10	0,56	20
G total	81.686,60	68	0,83	26
2016	Habitants (k)	Amputations	Amputations/ Habitants (m)	RR (%)
HB	675,1	0	0	0
SL	996,1	1	1,00	0
MV	1.611,50	0	0	0
HH	1.798,90	5	2,78	20
TH	2.164,40	1	0,46	0
ST	2.240,90	4	1,78	50
BB	2.489,70	1	0,40	100
SH	2.870,30	1	0,35	100
BE	3.547,40	3	0,85	0
RP	4.059,40	4	0,99	25
SN	4.083,30	3	0,73	33
HE	6.194,60	5	0,81	0
NI	7.936,10	4	0,50	75
BW	10.915,80	8	0,73	25
BY	12.887,10	12	0,93	8
NW	17.877,80	15	0,84	27
G total	82.348,70	67	0,81	25

(continued on next page)

**Table 4** (continued)

2014	Habitants (k)	Amputations	Amputations/Habitants (m)	RR (%)
2017	Habitants (k)	Amputations	Amputations/ Habitants (m)	RR (%)
HB	679,9	0	0	0
SL	995,4	3	3,01	0
MV	1.610,90	2	1,24	0
HH	1.820,50	2	1,10	100
TH	2.154,70	1	0,46	0
ST	2.229,70	3	1,35	67
BB	2.499,30	0	0	0
SH	2.885,90	0	0	0
BE	3.594,20	3	0,83	67
RP	4.069,90	4	0,98	75
SN	4.081,50	1	0,25	100
HE	6.228,20	4	0,64	25
NI	7.954,20	8	1,01	25
BW	10.987,70	5	0,46	60
BY	12.964,00	8	0,62	0
NW	17.901,10	8	0,45	50
G total	82.657,0	52	0,63	38
2018	Habitants (k)	Amputations	Amputations/ Habitants (m)	RR (%)
HB	680,6	0	0,00	0
SL	992,2	1	1,01	0
MV	1.609,6	1	0,62	0
HH	1.834,2	5	2,73	20
TH	2.145,5	2	0,93	50
ST	2.213,9	3	1,36	0
BB	2.506,6	0	0	0
SH	2.893,0	1	0,35	0
BE	3.624,9	4	1,10	0
RP	4.078,1	7	1,72	29
SN	4.075,3	1	0,25	0
HE	6.250,5	4	0,64	0
NI	7.978,9	6	0,75	0
BW	11.050,7	5	0,45	20
BY	13.038,7	11	0,84	18
NW	17.914,3	13	0,73	15
G total	82.887,0	64	0,77	14

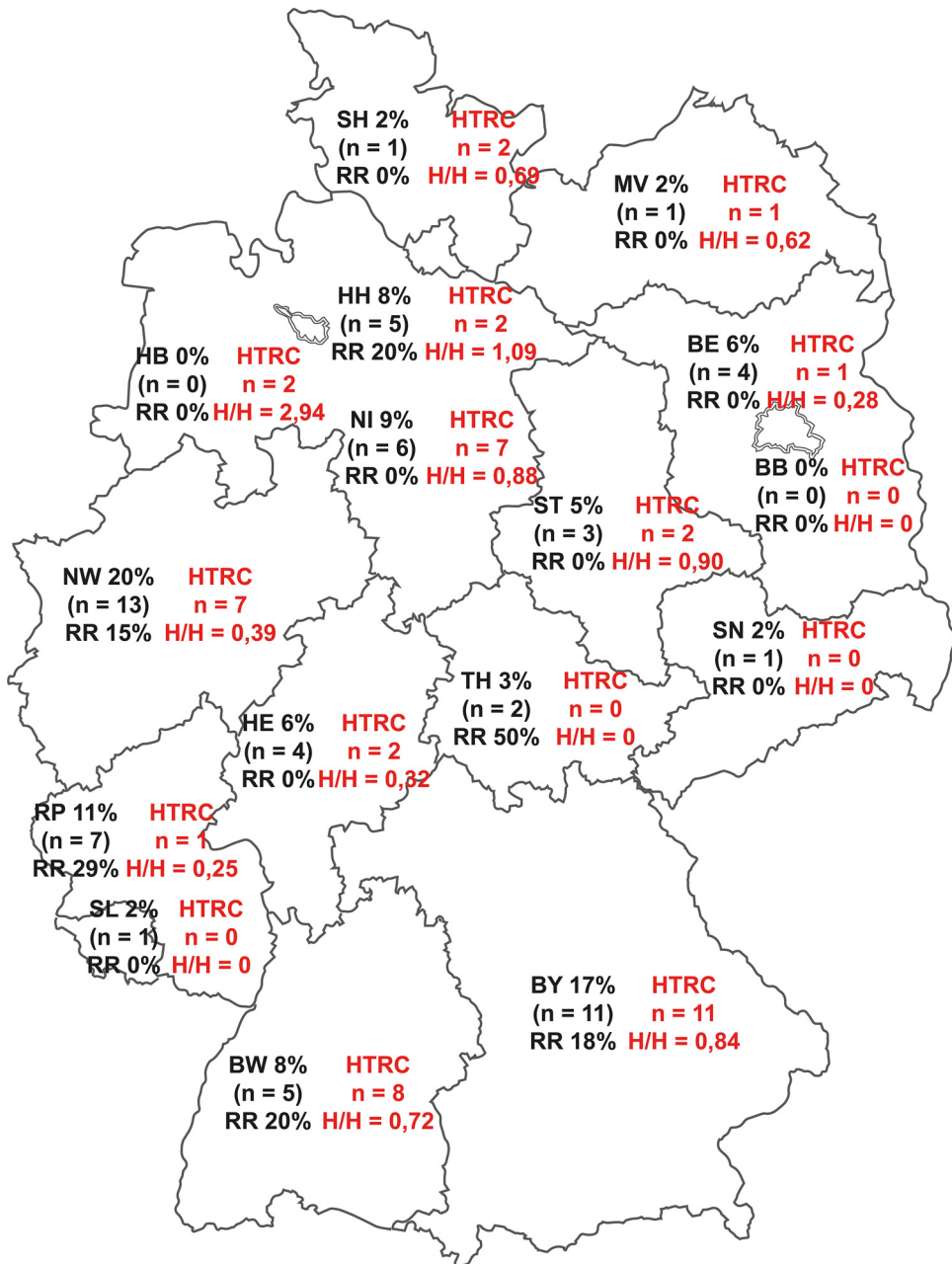
Number of habitants, absolute number of traumatic major upper extremity amputations, population-based amputation incidences and regional RRs in the German federal states for the years 2014–2018. Baden-Württemberg (BW), Bavaria (BY), Berlin (BE), Brandenburg (BB), Bremen (HB), Hamburg (HH), Hesse (HE), Lower Saxony (NI), Mecklenburg-West Pomerania (MV), North Rhine-Westphalia (NW), Rhineland-Palatinate (RP), Saarland (SL), Saxony (SN), Saxony-Anhalt (ST), Schleswig-Holstein (SH), Thuringia (TH), Germany (G).

## Discussion

Major upper limb loss implies grave functional as well as esthetical consequences, leading to significantly higher disability ratings than lower extremity amputations.<sup>8</sup> The National Trauma Data Bank (NTDB) recorded 1.386 trauma-associated major upper limb amputations in non-military patients in the United States between 2009 and 2012. These injuries affected most commonly the level of the humerus with 35%, the forearm with 30% and the hand with 14%.<sup>9</sup>

According to the national quality reports from 2014 to 2018, Germany counted a total of 329 major upper limb amputation injuries and 87 major upper limb replantations, yielding an overall RR of 26%. The international TR-DGU reported 23.7% replantations of trauma-related major amputations of the upper extremity.<sup>6</sup> In the US, the National Inpatient Sample of the Healthcare Cost and Utilisation Project recorded an overall RR of 14.5% for the years 2001, 2004, and 2007.<sup>2</sup> Though, data of the latter are not fully comparable, as the epidemiological analysis of Friedrich et al. includes minor upper extremity amputation injuries as well.<sup>2</sup>





**Fig. 2.** National distribution of major traumatic upper extremity amputations and replantation rates (RRs) as well as the absolute and per capita provision of FESSH-accredited hand trauma and replantation centres (HTRCs) in Germany, by federal states, in the year 2018. Relative (100%) and absolute amputation counts ( $n = 64$ ) as well as RRs (14%) related to the German federal states in 2018 are coloured black. Absolute ( $n = 46$ ) and per capita numbers (HTRC/1.000.000 habitants (H/H) = 0,55) of HTRCs related to the German federal states in 2018 are coloured red.

**Table 5**

Distribution of FESSH-accredited Hand trauma and replantation centres (HTRCs) within the German federal states, according to the population, amputation incidences, number of replantations and replantation rates (RRs) in the year 2018.

Federal state	HTRC	HTRC/ Habitant (m)	Amputations	Amputations in HTRCs n (%)	Amputations/HTRC	Replantations	Replantations in HTRCs n (%)	RR (%)	RR within HTRC (%)
Germany	46	0,55	64	29 (45%)	14	9	5 (56%)	14	17
Bavaria (BY)	11	0,84	11	7 (64%)	1	2	2 (100%)	18	29
Baden- Württemberg (BW)	8	0,72	5	0 (0%)	06	1	0 (0%)	20	0
Lower Saxony (NI)	7	0,88	6	4 (67%)	0,9	0	0 (0%)	0	0
North Rhine-Westphalia (NW)	7	0,39	13	0 (0%)	1,9	2	0 (0%)	15	0
Bremen (HB)	2	2,94	0	0 (0%)	0	0	0 (0%)	0	0
Hamburg (HH)	2	1,09	5	3 (60%)	2,5	1	1 (100%)	20	33
Hesse (HE)	2	0,32	4	2 (50%)	2	0	0 (0%)	0	0
Saxony-Anhalt (ST)	2	0,90	3	3 (100%)	1,5	0	0 (0%)	0	0
Schleswig-Holstein (SH)	2	0,69	1	1 (100%)	0,5	0	0 (0%)	0	0
Berlin (BE)	1	0,28	4	2 (50%)	4	0	0 (0%)	0	0
Mecklenburg-West Pomerania (MV)	1	0,62	1	0 (0%)	1	0	0 (0%)	0	0
Rhineland- Palatinate (RP)	1	0,25	7	7 (100%)	7	2	2 (100%)	29	29
Brandenburg (BB)	0	0	0	0 (0%)	0	0	0 (0%)	0	0
Saarland (SL)	0	0	1	0 (0%)	0	0	0 (0%)	0	0
Saxony (SN)	0	0	1	0 (0%)	0	0	0 (0%)	0	0
Thuringia (TH)	0	0	2	0 (0%)	0	1	0 (0%)	50	0

Million (m).

In Germany treatment of these complex injuries showed a trend towards a centralisation to medical teaching facilities from 2014 to 2018, which accounted for higher RRs compared with non-teaching facilities. This might reflect a rising general awareness for this complex injury entity, particularly amongst emergency services, as well as the high financial and infrastructural demands of replantation procedures. These data strengthen the observations of Chen and Narayan as well as Friedrich et al., that replantation procedures in the United States of America are associated with a huge economic burden and mainly performed in teaching, rather than non-teaching institutions.<sup>2,3</sup>

Between 2014 and 2018 most major amputation injuries affected the level of the wrist and forearm, as did replantation surgeries. Nevertheless, traumatic amputations between the shoulder and elbow were ranked amongst the top three ICD-10-GM codes throughout the investigation period. The lower replantation numbers, proximal to the elbow, might be amongst others attributed to the known less favourable functional replantation outcomes at these proximal levels.<sup>10–12</sup>

North Rhine-Westphalia, Bavaria and Baden-Württemberg, the cumulatively most populous German federal states, show high amputation incidences throughout the entire investigation period. Ratio calculations on the basis of population counts, however, revealed great discrepancies to these results, as the highest per capita amputation incidences were found in Hamburg, Rhineland-Palatinate and Saarland. Such substantial variances have to be considered in the development of treatment service.

While in the past, simple prosthetics had been the common treatment for trauma-related major upper limb amputations, the current therapeutical spectrum ranges from amputation, targeted reinnervation and bionic prosthetic fitting, microsurgical replantation to transplantation.<sup>13–15</sup> A functionally and aesthetically successful replantation of the proper limb remains frequently the most desired therapy of amputees. A comparison of patients who either received successful replantation or amputation and prosthetic fitting of the upper limb, between the level of the wrist and elbow, revealed superior patient-reported outcomes in the replantation group, with regard to overall function, activities of daily living and patient satisfaction.<sup>16</sup> However, replantation is not always feasible. While a poor condition of the amputate or amputee e.g., might unchangeably preclude a replantation procedure, limiting factors such as time of ischemia, infrastructural setting, surgical expertise and workforce represent conquerable restrictions. As a result, specialised hand trauma and replantation centres have been established in Europe within the last years and are still developing. Ideally, medical primary care is performed in a specialised hand trauma centre. In 2018 HTRCs performed 56% of the major upper limb replantations in Germany, whilst accounting for a RR of 17%, compared to an RR of 14% in medical teaching facilities in this year. These numbers underline the importance of these specialised centres. To enable a comprehensive, nation- and Europe-wide coverage of these trauma centres, knowledge about provision and demand is required. Thus, information about current trauma incidences as well as their geographical distribution within a country, a continent or a confederation is crucial to ensure optimal delivery of care.

Looking at the example of Germany reveals that there was already quite a high density of HTRCs in the south and west of the country in the year 2018. More specifically, drawing an imaginary line from the north to the south of Germany, in order to divide its federal states into east and west, we actually found a disbalance in distribution of HTRCs in 2018 (HTRCs in the east  $n = 15$ , HTRCs in the west  $n = 31$ ; or rather HTRCs in the former German Democratic Republic  $n = 4$ , Federal Republic of Germany  $n = 42$ ). It is further striking that Saarland and Rhineland-Palatinate, in the southwest of Germany, which recorded the second and third highest incidences of major upper limb amputations per habitant, were equipped with only a single HTRC in 2018. Certainly, the demand of these federal states might be compensated by the HTRCs of the neighbouring federal states. However, surveillance would be necessary to draw valid conclusions from such observations.

Ideally, supply and need would be regularly controlled by means of a comprehensive and accurate trauma registry for major extremity amputations. In contrast to voluntary trauma registries, the legal regulation for quality reporting in Germany allows a reliable and nationwide analysis of these injury entities. However, quality reports bear some shortcomings. For example, diagnoses and procedures recorded in quality reports originate from hospital invoicing data exclusively. As a consequence, they do not provide any demographic or outcome information about the recorded amputations and replantations. Injury mechanism, limb ischemia time, life-threatening concomitant injuries or other circumstances might have restricted the indication for replantation, as well, though, not captured by

the quality reports and therefore representing a clear limitation of this study. Replantation outcome data, however, should be an integral part of any future trauma registry.

For reasons of data protection, quality reports of German hospitals do not specify the number of treated amputation injuries and performed replantations within the individual medical institutions per year if it was below four. In fact, none of the included institutions exceeded this cut-off with regard to replantations. Considering the relative rarity of major upper limb amputations and replantations, the number one, as the smallest possible number, was assumed in these cases, hazarding a potential underestimation of replantation counts.

It should further be considered that irregularities in data reporting within the individual hospitals cannot be ruled out. Thus, there might be traumatic major upper extremity amputations or replantations which were not recorded or incorrectly encoded. In addition, the amputation injury itself might have occurred in a federal state different from the place of care, which might bias the results of this study.

To our best knowledge, this is the first national data report on traumatic major upper extremity amputations in Germany, analysing amputation levels and geographical distributions as well as the treating medical institution. The study shows that major upper extremity amputation injuries remain a serious issue in developed and politically stable countries, such as Germany.

The provision of highly specialised therapy, in terms of logistics, infrastructure as well as medical workforce and expertise, in highly specialised centres for highly complex injuries is a future challenge in replantation surgery. This data contributes to a future demand-adapted reorganisation of these specialised hand trauma centres.

This need gains even more weight considering the severity and frequently highly disabling consequences of these injuries. Surveillance represents the key measure for a proper and need-adapted implementation of such therapeutical improvements. This study suggests one way for comprehensive injury surveillance by use of a standardised reporting scheme, the obligatory annual German quality reports. Regional as well as per capita variations in the emergence of upper limb amputations and number of replantations are crucial factors to guide infrastructural service development. These data, and hopefully future reports, provide vital epidemiologic information, substantially impacting future national structuring of hand trauma centres in order to improve treatment of these devastating injuries. At the same time, they demonstrate the difficulty with data availability and quality, amongst others due to voluntariness of participation, data protection regulations or accuracy of recorded data.

The obligatory character of the German quality reports allows for comprehensive data collection and thus, represents a clear advantage of this reporting scheme. However, demographic data, mechanism of injury, time of ischemia, postoperative course as well as replantation outcome data, should be an integral part of any future registry for this trauma entity. Regarding upper limb transplantations, such information is already recorded by the International Registry on Hand and Composite Tissue Transplantation (IRHCCT), though registry participation happens on a voluntary basis.

This study provides a first step toward a standardised and comprehensive national, or rather European surveillance program for traumatic major upper extremity amputations and replantations, while underlining the importance of such a database for optimisations in delivery of care.

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## **Ethics**

Ethical approval to report these data was waived by the Ethics Committee of the Hannover Medical School.

## **Declaration of Competing Interest**

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpra.2022.01.002.

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