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Comparison of Closed and Open Surgical Technique for Second to Fifth Metacarpal Shaft Fractures: A Multicenter, Retrospective Study in a Dutch City Population

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Abstract: The aim of this study was to assess surgical treatment in metacarpal shaft fractures of the second to fifth ray to determine the functional outcomes and complications in open reduction and internal fixation (ORIF) versus closed reduction and internal fixation (CRIF). This was a retrospective study that included patients with metacarpal shaft fractures of the second to fifth rays who were treated surgically between 1 January 2007 and 31 December 2019. Functional outcomes were scored using the QuickDASH and Eq5D score. A total of 231 treated patients were included. Single fractures were seen in 180 patients, and multiple fractures in 51 patients. ORIF was applied in 141 patients and CRIF in 90 patients. The functional outcomes were not significantly different between the groups. Complications were found in 41 (29%) of the ORIF patients and 15 (17%) of the CRIF patients. The functional outcomes after single or multiple metacarpal shaft fractures were similar in the ORIF and CRIF patients. ORIF showed significantly more complications, such as functional impairment and infections and a higher reoperation rate. In conclusion, CRIF is as safe as ORIF for the surgical treatment of metacarpal shaft fractures in terms of its functional outcome and slightly preferable due to its lower complication rate.

Keywords: metacarpal fractures; surgical treatment; closed reduction internal fixation; functional outcomes

Citation: Quax, M.L.J.; Kielman, M.; Meylaerts, S.A.; Greeven, A.P.A. Comparison of Closed and Open Surgical Technique for Second to Fifth Metacarpal Shaft Fractures: A Multicenter, Retrospective Study in a Dutch City Population. *Surgeries* **2024**, *5*, 264–272. https://doi.org/10.3390/surgeries5020024

Academic Editor: Cornelis F. M. Sier

Received: 21 February 2024
Revised: 30 March 2024
Accepted: 11 April 2024
Published: 18 April 2024

1. Introduction

Fractures of the hand and wrist count for 17–19% of all fractures of the skeletal system, and metacarpal fractures account for 36% of all hand and wrist fractures [1–4]. Most of these fractures occur in the age group between 20 and 40 years and result in significant societal costs [5]. These societal costs are mostly due to a longer return-to-work time after fractures of the hand and rehabilitation time.

Sub-capital metacarpal fractures of the fifth ray and metacarpal fractures of the first ray make up the majority of metacarpal fractures, and shaft fractures of the second to fifth rays represent a smaller percentage of hand fractures [6]. Most metacarpal shaft fractures are treated non-operatively. Studies have shown that non-operative treatment is successful in a significant percentage of metacarpal fractures, particularly those that are not severely displaced or angulated [7]. However, sometimes, surgical treatment is necessary. The exact percentage can vary widely. In some studies, non-operative treatment has been successful in up to 80–90% of cases, while in others, the success rate may be lower, around 60–70%.

Ultimately, the decision to pursue non-operative treatment for a metacarpal fracture should be made on a case-by-case basis, taking into account factors such as the specific characteristics of the fracture and the patient's individual circumstances.

Operative treatment is indicated in cases of angulation, malrotation, longitudinal shortening, multiple fractures, and fractures with associated soft tissue injury or bone loss [6–9]. When malrotation, angulation, shortening, or multiple fractures are diagnosed, the treatment strategy starts with shared decision making. In low-demand geriatric patients, non-operative treatment can be chosen in situations where young patients would be treated surgically.

Surgical treatment can be performed by open reduction and internal fixation (ORIF) or closed reduction and internal fixation (CRIF). The advantage of open reduction and internal fixation is stable fixation in an anatomical position, which allows for early mobilization postoperatively. The disadvantage of open reduction and internal fixation is soft tissue damage due to dissection, with the risk of adhesions and postoperative stiffness and impaired function. With the advantages of open reduction and internal fixation, combined with a reduction in infection rate due to the use of perioperative antibiotics, surgeons have more frequently decided for open reduction and internal fixation in comparison to closed reduction and internal fixation in the last two decades [6–8,10–12]. In the meantime, several papers have published the outcomes of different percutaneous techniques in recent years [4,6,9,13–15]. Although the discussion on the preferred surgical fixation is still ongoing, a recent analysis based on a systematic review suggested that open reduction and internal fixation is less favorable than percutaneous fixation in the treatment of single metacarpal shaft fractures [5]. Although both techniques showed good functional outcome, a large percentage of the ORIF-treated patients experienced functional impairment, requiring re-operation in 17% compared to no re-operations in the CRIF group.

The systematic review argued that ORIF might be a less preferred surgical technique in comparison to CRIF in the treatment of a single metacarpal shaft fracture. Further research was suggested to focus on the comparison between ORIF and CRIF for single and multiple metacarpal shaft fractures. A randomized clinical trial would be difficult for multiple reasons. The current study is an extension of the retrospective study by Greeven et al. [16,17], adding an additional 89 patients to the 142 presented in the unpublished chapter of this thesis. The current study was, therefore, designed to confirm the results of the previous review to substantiate these results in a large comparative dual-center study and, therefore, confirm that the closed percutaneous technique can be safely used in the treatment of metacarpal shaft fractures of the second to fifth rays.

2. Materials and Methods

This retrospective study was performed in two Level I Trauma Centers in the Netherlands, after the institutions' ethics committees' approval was given (METC South Holland, 17-148, 7 December 2017). Patients' eligibility was checked with an electronic search in the Digital Patients Medical Database using diagnostic codes, treatment codes, and (erroneous) spelling varieties of "Metacarpal fracture". All patients treated between 1 January 2007 and 31 December 2019 were included. The inclusion criteria were single or multiple metacarpal shaft fractures, second to fifth rays, surgically treated with closed reduction percutaneous fixation (CRIF) or open reduction internal fixation (ORIF) and a minimum age of 16 years at the time of injury. The exclusion criteria were non-shaft fractures and patients who were not able to participate in the functional outcome queries.

Patients typically exhibit pain localized at the fracture site, accompanied by dorsal swelling of the hand and a diminished range of motion. Fracture location and characteristics may lead to malrotation, scissoring, aesthetic deformities of the knuckle, and extensor lag. Injuries resulting from high-energy trauma present added complexity, potentially involving soft tissue trauma, neurovascular injury, concomitant fractures, and an increased risk of infection in cases of open fractures.

Accurate diagnosis relies heavily on high-quality radiographs. Most fractures can be effectively identified using anteroposterior (AP) or posteroanterior (PA) views, as well as semi-pronation and lateral views. However, poorly positioned images can lead to missed or misdiagnosed fractures. In a lateral view, proper alignment should show the pisiform superimposed on the distal pole of the scaphoid. The true anteroposterior view, commonly referred to as the Robert's view, provides optimal visualization. Obtaining a semi-pronated (or oblique) view involves resting the hand on its ulnar border in a neutral position and then pronating it at a 40° to 45° angle.

Of all included patients, the baseline characteristics were noted from the patient's medical record, together with any additional injuries and the type of surgery applied. AO–Müller classification was used to classify the fractures [18]. The metacarpal fractures were categorized using the AO–Müller classification system, which stratifies fractures according to their morphological characteristics and severity. In shaft fractures, type A denotes simple fractures, type B signifies wedge-type fractures, and type C represents multifragmentary fractures. [18] Radiological evaluations were undertaken to ascertain the extent of angulation, translation, shortening, and malrotation, with established thresholds employed to inform the treatment decisions.

Like neck fractures, a certain degree of apex dorsal angulation is deemed acceptable for these fractures. There is a notable increase in the allowable angulation from the radial to the ulnar side due to the enhanced mobility of the carpometacarpal joints on the ulnar side. While the specific extent of deformity may vary among references, the acceptable dorsal angulation typically falls below 10° in the index and middle fingers, 20° in the ring finger, and 30° in the small finger. Shortening of the bone, which can result in cosmetic alteration of the knuckle may occur but often does not lead to functional impairments. Indications for intervention in these fractures encompass angulation, as previously described, bone shortening leading to an extensor lag and malrotation or scissoring. However, rigid cut-off values for translation and shortening are not universally applied.

Consensus in diagnosis was reached by discussion. The fracture mechanisms were divided into fall, hit, crush, and "other". "Other" consisted of road traffic accidents, direct impact, or multi-trauma. In the operation indication, "other" consisted of delayed union, risk of pseudo-arthrosis, open fracture, or instable fracture.

The outcome was evaluated by analyzing the postoperative complications and reoperations. A functional assessment was conducted using the QuickDASH and Eq5D queries, as described by previous studies [19,20]. Functional impairment, ranging from none to complete loss of function, was objectively scored. This assessment was performed at a follow-up period of 1 year after treatment.

The functional impairment was objective and scored from no functional impairment, marginal and moderate functional impairment, to complete loss of function.

Complications were divided into functional, cosmetic, infectious complications, pain and "other". "Other" was edema, osteosynthesis break, radiological failure, or complaints of osteosynthesis.

Statistical Analysis

The Statistical Package for Social Studies (SPSS Inc. Chicago, DE, USA) Version 24.0 was used for all statistical analyses. An 80% power calculation was conducted (incidence difference of 15%, alpha of 0,05) and showed a sample size of 276.

The normality of the data was evaluated using a Shapiro–Wilk test. Since all continuous data deviated from the normal distribution, they are shown as the median with P25–P75. The categorical data are shown as numbers with percentages. The statistical significance of the differences between the ORIF and CRIF group was tested using the Mann–Whitney U-test (for continuous variables), and the Chi-squared or Fisher's Exact test (for categorical variables). A 2-sided p-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Patient Characteristics

The search identified 231 patients that could all be included (Table 1). The median age was 33 years (SD 12). One-hundred sixty-one patients were male (70%). The right hand was injured in 124 patients (54%). The mechanism of injury was most frequently related to a fall from standing height (44%). Other trauma mechanisms were a hit (29%) or crush injury (4%). Thirty percent of the patients did smoke. The medical history showed no relevant injuries or illnesses prior to the treatment of the metacarpal shaft fracture.

Table 1. Patient characteristics.

Characteristics	n = 231	%	ORIF n = 141	%	CRIF n = 90	%
Age (SD)	33 (12)		31 (8.6)		40 (15.2)	
Male	161	70%	101	72%	60	67%
Smoking *	69	30%	48	34%	21	23%
Right fractured	124	54%	88	62%	36	40%
Dominant side fractured	152	66%	112	79%	40	44%
Multiple fractures	92	40%	71	50%	21	23%
Trauma mechanism						
Fall	102	44%	51	36%	51	57%
Hit	67	29%	45	32%	22	24%
Crush	8	3.5%	3	2.1%	5	5.6%
Other	54	23%	32	23%	12	13%

* Missing for 16 patients.

3.2. Fracture Characteristics

The fracture characteristics are separately reported (Table 2). Most of the fractures were AO–Müller type A (63%), then types B (30%) and C (17%).

Table 2. Fracture characteristics.

Fracture Characteristics	Total n = 231	%	ORIF n = 141	%	CRIF n = 90	%
Fracture type						
A	147	64%	90	64%	57	63%
B	70	30%	44	31%	26	29%
C	40	17%	7	5%	7	7.8%
Single fracture	180					
Second ray	12	5.2%	8	5.7%	4	4.4%
Third ray	26	11%	23	16%	3	3.3%
Fourth ray	62	27%	43	31%	19	21%
Fifth ray	80	35%	49	35%	31	34%
Multiple fractures	51					
II + III + IV	4	1.7%	1	0.7%	3	3.3%
II + III + IV + V	1	0.4%	1	0.7%	0	0%
III + IV	15	6.5%	11	7.8%	4	4.4%
III + IV + V	6	2.6%	3	2.1%	3	3.3%
III + V	0	0%	0	0%	0	0%
IV + V	25	11%	15	11%	10	11%
Operation indication						
Shortening	81	35%	59	42%	22	24%
Rotation	47	20%	19	14%	26	29%
Transverse	46	20%	33	23%	13	14%
Angulation	37	16%	19	14%	18	20%
Other	20	8.7%	11	7.8%	8	8.9%

A total of 51 patients were treated for multiple fractures, and 180 patients had a single fracture. ORIF was applied in 141 patients, and CRIF in 90 patients. The most frequently treated type of fracture was a shortened fracture in 81 patients (35%). Less frequent were rotated fractures (20%), transverse dislocated fractures (20%), and significantly angulated fractures (16%). Rotational deformities were treated by CRIF in 47%.

3.3. Treatment Characteristics

The choice for the type of treatment was based on the personal preference of the surgeon (Table 3). The fixation type was most frequently plate and screw fixation in the ORIF group, and transverse K-wire fixation in the CRIF group. ORIF was performed on 31 out of 51 multiple fractures. The mean time to surgery was 8 days. The surgery time was significantly shorter for the percutaneous than for the open technique, i.e., 22 (P25–P75 14–29) vs. 50 (P25–P75 34–69) minutes. Postoperative cast immobilization was carried out in 18% of the ORIF patients (n = 26) and in 98% of the CRIF patients.

Table 3. Treatment characteristics.

Treatment Characteristics		*n* = 231	ORIF *n* = 141	CRIF *n* = 90	*p*-Value
Time to surgery	(days)	7.6	8.6	6.1	0.325
Surgery time	(minutes)	36	50″ (30–69)	22″ (14–29)	<0.001
	Single fracture		49″	19″	
	Multiple fractures		84″	30″	
Fixation type					
	Single fracture		46x screw 64x plate	43x trans 3x EF	
	Multiple fractures		12x screw 19x plate	1x trans 19x IM + trans	
Cast immobilization					
	Number of patients	114 (49%)	25 (18%)	89 (98%)	
	Duration (weeks)	2.3	0.5	4	

ORIF = open reduction and internal fixation; CRIF = closed reduction and percutaneous fixation; IM = intramedullary K-wire fixation; trans = trans-metacarpal K-wire fixation; ″ = minutes. Data are shown as median (P25–P75) or as n (%).

3.4. Functional Outcome

No significant difference between the two groups was found. The mean QuickDASH was 4.3, and the mean Eq5D was 75.3. No significant differences in complications were found among the fracture types. No significant difference was found between cast immobilization and direct mobilization after ORIF (p = 0.61). Multiple fractures did not result in worse functional outcome than single fractures. The complication rate was significantly different (p = 0.02).

Complications were found in 41 (29%) ORIF patients and 15 (17%) CRIF patients. Re-operation was performed on 25 patients—22 in the ORIF group, and 3 in the CRIF group. Of the re-operations, three re-fixations were performed, three rotational deformities were corrected, three re-operations were performed due to infection, and two were performed due to pain. Four patients experienced functional impairment and were re-operated on, requiring hardware removal and extensor tendon release. Nine patients experienced issues with the osteosynthesis material and required removal of the material.

Postoperative infections were observed in fourteen patients. Ten ORIF patients were treated with intravenous antibiotics, and two required a second operation for wound debridement. Two CRIF patients developed a pin-tract infection; they were treated with oral antibiotics and K-wire removal after fracture healing and made a full functional recovery.

Persistent pain was seen in five patients. In total, three ORIF patients reported persistent pain. Two of these patients were re-operated for this reason. These operations consisted of extensor tendon release and removal of the osteosynthesis material. Significant functional impairment was found in 11 (7.8%) ORIF patients. Of these, three patients required a second operation (Table 4). In total, complications were found in 32 (23%) ORIF patients and 15 (17%) CRIF patients.

Table 4. Overall outcomes by surgery type.

Outomces	*n* = 231	%	ORIF *n* = 141	%	CRIF *n* = 90	%	*p*-Value
QuickDASH (SD)	4.3		5.1 (9.3)		3.9 (7.5)	0.41	
Eq5D (SD) *	75.3 (21.5)		78 (21.3)		72.8 (21.8)		0.366
Complications	47	20%	41	29%	15	17%	0.024
Functional impairment	19	8.2%	11	7.8%	8	8.9%	
Infection	14	6.1%	12	8.5%	2	2.2%	
Cosmetic	3	1.3%	2	1.4%	1	1.1%	
Pain	5	2.2%	3	2.1%	2	2.2%	
Neurologic	4	1.7%	3	2.1%	1	1.1%	
Other	11	4.8%	10	7.1%	1	1.1%	
Reoperation	25	11%	22	16%	3	3.3%	0.003
Indication reoperation							
Irritation	9	3.9%	9	6.4%	0	0%	
Functional impairment	4	1.7%	3	2.1%	0	0%	
Rotational deformity	4	1.7%	3	2.1%	1	1.1%	
Infection	3	1.3%	2	1.4%	0	0%	
Refixation	3	1.3%	3	2.1%	1	1.1%	
Pain	2	0.9%	2	1.4%	1	1.1%	

* Missing for 108 patients.

4. Discussion

This study shows comparable functional outcomes after ORIF or CRIF in single and multiple metacarpal shaft fractures. Significantly more complications were reported by patients after ORIF, with 29% versus 17% in CRIF. Functional impairment and infectious complications were the most reported. In the ORIF group, 22 out of 141 patients needed to be re-operated on, and for the CRIF group, 3 out of 90 CRIF patients required a second operation. Most re-operations were performed due to irritation from the osteosynthesis material. In the patients' reports, irritation was described as the reason for the removal of the osteosynthesis material. Mostly, patients had discomfort due to the palpable screws and plates.

When comparing the functional outcomes, no differences were observed in the QuickDASH or Eq5D scores. The previous literature showed no clear preference for ORIF or CRIF, except for the study by Dreyfuss et al. [21], who found better function and fewer complications from ORIF in 74 patients. In the systematic review, Greeven et al. described a preference for CRIF in their published study due to the reoperation rate in ORIF [5]. As a result of the lack of a large cohort or retrospective studies, no consensus has been reached for the surgical treatment of metacarpal shaft fractures. In clinical practice, surgeons choose ORIF more often in multifragmentary fractures and more complex fractures (e.g., open fractures). This is expert-based, and our study shows that in the objective analysis of the outcome data, CRIF is as safe as ORIF. The current cohort included 231 patients, which is one of the biggest reported cohorts. The comparable DASH scores (5.1 in ORIF vs. 3.9 in CRIF) suggest that both CRIF and ORIF are viable treatment options. This insight can be implemented into the current knowledge and is directly applicable in daily clinical practice.

This study analyzed CRIF versus ORIF in fracture groups, where specific fracture types and trauma mechanisms need specific analysis. The current study is underpowered to perform this subgroup analysis. In this subgroup analysis, the trauma mechanism, multiple fractures, and specific fracture patterns could be analyzed properly.

An earlier paper that combined the data of five smaller cohorts reported a re-operation rate of 17% in ORIF-treated patients [5], which is similar to the relatively high percentage of 16% re-operations in the ORIF patient group we report here, confirming that our results obtained in our large cohort study are representative. An explanation for the re-operations after ORIF maybe that they are the result of a trade-off between the anatomical restoration of the injured metacarpal bone and the consequences of exposure of the fracture site, specifically soft tissue irritation and scar formation [22]. The current study substantiates these earlier review results in a larger patient group in two Level I Trauma Centers. This retrospective comparative study, therefore, strengthens these earlier findings. Especially the percentages of complications and re-operations are of clinical significance and could be used during the shared decision-making process whilst informing the patient of the benefits and risks related to the operation [23].

Cast immobilization after ORIF resulted in 3 of these 25 patients developing functional impairment postoperatively. An advantage of open surgery is direct functional mobilization in comparison to the percutaneous technique, thereby preventing scar formation between the moving anatomical layers, otherwise resulting in a limitation of movement of the hand. The importance of direct mobilization after ORIF underscores the clinical significance of this finding. The aim of ORIF in hand surgery, therefore, should be stabilization enabling direct mobilization. When no stability can be reached and postoperative cast immobilization seems necessary, immobilization should be as short as possible. The decision to employ cast immobilization post-ORIF hinges upon several factors. Firstly, concerns regarding the stability of the osteosynthesis may prompt clinicians to opt for this conservative approach to ensure optimal healing conditions. Furthermore, in cases characterized by multiple fractures where not all segments are rigidly fixated, cast immobilization serves as an additional safeguard against displacement or misalignment. Additionally, the application of casts post-ORIF may be motivated by the imperative to shield delicate soft tissues or wounds from potential complications, such as infections. In the literature, novel forms of immobilization have been documented for the non-surgical management of metacarpal shaft fractures [24]. These splints provide immobilization while safeguarding the fractures to promote optimal healing. In the current clinical practice, hand injury-specialized physiotherapists custom-design splints tailored to individual cases to optimize the functional outcomes. These splints can also be employed in the postoperative management of surgically treated fractures. In cases of closed reduction and internal fixation, cast immobilization is typically employed in 98% of instances. However, the integration of these bespoke splints into postoperative care has the potential to mitigate postoperative stiffness, leading to further enhancement of the functional outcomes.

According to the literature, little is known regarding the outcome and complications in the treatment of multiple fractures. In the current study, multiple fractures were observed in 51 patients, 31 patients were treated with ORIF, and 20 patients with CRIF. Ozer et al. described their preference for ORIF due to the safe technique with a low complication rate [25]. This study focused on all metacarpal shaft fractures, but the subanalysis showed comparable functional outcomes after ORIF and CRIF in multiple fractures. According to these results, multiple fractures can safely be treated by CRIF.

A possible limitation of the current study is the misbalance between the number of patients treated with ORIF and CRIF. However, this study is the largest study reporting solely on metacarpal shaft fractures without any patients lost to follow-up, underscoring the clinical importance of this analysis. Another limitation is that the choice for ORIF or CRIF was made by the surgeon based on personal preference. Selection bias, therefore, will be present. The fracture type could be a reason to choose the open or closed technique, as described above. Within the CRIF group, mostly spiral, oblique, and transverse fractures were seen. Comminuted fractures were mostly treated with ORIF. Therefore, spiral, oblique, and transverse fractures can be treated with CRIF without the risks associated with ORIF. No significant differences in complications were found among the fracture types.

In the management of metacarpal fractures, the complexity of the fracture plays a crucial role in determining the choice between open or closed reduction techniques. For instance, in cases of open fractures or those characterized by multifragmentation, where closed reduction may be challenging, open reduction is often preferred due to its ability to provide better visualization and manipulation of the fracture fragments. Conversely, for simpler fractures, such as rotated or wedge fractures, closed reduction and fixation is anticipated to result in minimal soft tissue damage and subsequent adhesion formation.

When closed reduction proves difficult, as observed in instances of transverse dislocated fractures, multifragmented fractures, or shortened fractures where closed reduction is unsuccessful, open reduction is expected to yield superior functional outcomes. These findings underscore the importance of tailoring the treatment approach based on the specific characteristics of the fracture, with open reduction favored in cases where closed reduction is deemed inadequate.

Furthermore, the fracture type significantly influences the selection of the appropriate technique, whether open or closed. Analysis of Table 1 revealed no significant disparities among the fracture types and their corresponding treatments. However, within the CRIF group, predominantly rotated fractures were encountered, while comminuted, shortened, and transversely dislocated fractures were primarily managed using ORIF. This preference for ORIF in cases requiring a more precise reduction aligns with the observed tendency to achieve better functional outcomes with this technique.

Overall, while fracture type guides the choice between open and closed reduction techniques, the decision-making process remains nuanced, with consideration given to the specific characteristics of the fracture and the desired treatment outcomes. These insights contribute to a comprehensive understanding of the management strategies employed in metacarpal fractures and underscore the importance of individualized treatment approaches in optimizing patient outcomes. Our study confirms the thoughts that earlier studies have published, namely that both CRIF and ORIF are safe techniques for surgical treatment. These earlier published, small-cohort studies were lower-powered and ambivalent in their preferential treatment. Our study, with the largest available cohort, concludes that both surgical techniques are safe to perform on metacarpal fractures.

In conclusion, we describe the outcomes of surgical treatment in the largest cohort studied thus far of metacarpal shaft fractures, showing no differences in the functional outcomes and a small advantage in the complication rate when treatment with closed reduction and internal fixation is performed. Previously, smaller studies showed a small preference for open reduction and internal fixation. However, this study shows that metacarpal shaft fractures can be treated safely by closed reduction and internal fixation due to the fact that it is performedwith 231 patients with only metacarpal shaft fractures and a comparison of the outcomes and complications of the two treatment options,. This makes our comparative study of these specific types of fractures and treatment options unique in its kind and may be helpful for defining treatment strategies.

Author Contributions: Conceptualization, M.L.J.Q., S.A.M. and A.P.A.G.; methodology, M.L.J.Q.; formal analysis, A.P.A.G. and M.L.J.Q.; investigation, M.L.J.Q.; data curation, M.K. and M.L.J.Q.; writing—original draft and editing, M.L.J.Q.; supervision, A.P.A.G. and S.A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of South Holland of Leiden University Medical Centre (17-148, 7 December 2017).

Informed Consent Statement: For all patients, informed consent was obtained.

Data Availability Statement: No new data was created.

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

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