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[Risque de dissémination septique au cours de la prise en charge chirurgicale des phlegmons de la gaine des tendons fléchisseurs: Exsanguination par compression mécanique versus surélévation simple]**

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**Risk of septic spread during surgical management of digital flexor tendon sheath
phlegmon: Exsanguination by mechanical compression versus simple elevation**

**Risque de dissémination septique au cours de la prise en charge chirurgicale des
phlegmons de la gaine des tendons fléchisseurs : Exsanguination par compression
mécanique versus surélévation simple**

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Risk of septic spread during surgical management of digital flexor tendon sheath phlegmon: Exsanguination by mechanical compression versus simple elevation

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Abstract

This study aimed to demonstrate that there was no risk of extension of infection in performing mechanical exsanguination before inflating the tourniquet for surgical treatment of digital flexor tendon sheath phlegmon. The series comprised 96 patients, with a mean age of 47 years (range, 18–87 years) and 37 women. Group I included 47 patients in whom exsanguination was performed with a Velpeau band before inflating the pneumatic tourniquet at the root of the limb. In Group II, which included 49 patients, the tourniquet was inflated after simple elevation of the limb. Six patients underwent revision surgery for recurrence or osteoarticular complications: 4 (8.5%) in Group I and 2 (4.1%) in Group II, the difference between two groups being non-significant ($p = 0.6378$). In conclusion, mechanical exsanguination before inflating the tourniquet did not incur risk of complications in surgical management of digital flexor tendon sheath phlegmon.

Résumé

Le but de ce travail était de démontrer qu'il n'y avait aucun risque d'extension de l'infection à procéder à une exsanguination mécanique avant de gonfler le garrot au cours du traitement chirurgical des phlegmons de la gaine des tendons fléchisseurs des doigts. Notre série comprenait 96 patients âgés en moyenne de 47 ans (18-87) dont 37 femmes. Le groupe I comprenait 47 patients chez qui une exsanguination a été réalisée avec une bande Velpeau avant de gonfler le garrot pneumatique à la racine du membre. Dans le groupe II qui comprenait 49 patients, le garrot pneumatique a été gonflé après surélévation du membre

seulement. Dans cette série, 6 patients ont été repris pour récurrence ou extension ostéoarticulaire, dont 4 (8,5%) pour le groupe I et 2 (4,1%) pour le groupe II. La différence entre les deux groupes était statistiquement non significative ($p = 0,6378$). En conclusion, l'exsanguination mécanique avant de gonfler le garrot ne présente pas de risque de complication lors de la prise en charge chirurgicale des phlegmons de la gaine des fléchisseurs des doigts.

Keywords: Infection; sepsis; Phlegmon; Flexor tendon; Tourniquet

Mots-clés : Infection ; Sepsis ; Phlegmon ; Tendons fléchisseurs ; Garrot

1. Introduction

There is a dogma in surgical treatment of all infected limbs and phlegmons of the digital flexor tendon sheaths: one should not perform mechanical exsanguination of the upper limb before inflating the pneumatic tourniquet at the risk of causing proximal septic spread [1,2]. However, simple elevation of the limb makes the surgical procedure more difficult because of the persistence of a certain volume of blood in the limb, which can, despite the tourniquet, cause blood to ooze continuously [3,4].

The present study aimed to demonstrate that there is no risk in performing mechanical exsanguination before inflating the tourniquet during surgical treatment of digital flexor tendon sheath phlegmon.

The main hypothesis was that the rate of revision surgery after lavage with or without synovectomy of the flexor tendon sheaths was not greater when mechanical exsanguination was performed before inflating the tourniquet.

2. Patients and methods

The local review board approved this retrospective study (Reference CE-2020-204).

One hundred and eight patients were treated in our department from January 2018 to September 2020 for phlegmon of the flexor tendon sheath. Diagnosis was founded on presence of at least one of Kanavel's cardinal signs [5] (pain on palpation along the flexor tendon path, digital flexion contracture, pain on passive extension of the finger, finger edema), supplemented by ultrasound scan of the diseased finger screening for $\geq 20\%$ increase in sheath diameter compared to the contralateral side [6]. Patients under the age of 18, pregnant women, with associated osteoarticular disorder, and with <2 weeks' follow-up were excluded. The series included 96 patients, with a mean age of 47 years (range, 18-87 years), including 37 women. Comorbidities, mechanism, injury agent and affected finger are shown in Tables 1 and 2.

All the patients were treated in an outpatient hand trauma center under locoregional anesthesia by 8 level-3 surgeons and 2 level-4 surgeons [7]. Surgical treatment consisted in

proximal to distal saline lavage of the flexor tendon sheath until the liquid flow became perfectly clear. Depending on phlegmon stage (stage 1: cloudy fluid, no synovitis; stage 2: suspicious or purulent fluid, synovitis but intact tendon; stage 3: tendon necrosis) [8], a synovectomy was performed in some cases.

After bacteriological sampling, a broad-spectrum antibiotic loading dose (amoxicillin / clavulanic acid or clindamycin) was delivered intraoperatively and continued postoperatively. The antibiotic treatment was then adapted to the results of the antibiogram after consulting an infectious diseases specialist.

In the first 47 cases (group I), mechanical exsanguination was performed with a Velpeau band from the hand to the upper arm before inflating the pneumatic tourniquet at the root of the limb. In the following 49 cases (group II), the upper limb was kept elevated until the superficial veins appeared empty before inflating the pneumatic tourniquet.

Revision surgery was indicated whenever local, regional and/or general infectious signs did not decrease or reappeared within 8 days after primary surgery.

Data collection consisted in reviewing medical files for surgical revision for recurrence and/or extension of the infection.

Statistical analysis first checked normal distribution in the 2 groups on Shapiro-Wilk test. Quantitative variables were compared between groups by Student test (when the variable of interest was Gaussian), with a possible correction for the heterogeneity of variances on Welch test, or else by non-parametric Mann-Whitney-Wilcoxon test. Number of surgical revisions for recurrence and/or extension of the infection (qualitative variable) was compared between groups by Fisher exact test, with alpha risk of 5%. Analyses used R software version 4.0.2 (RStudio, Inc.) and all requisite software packages.

3. Results

Results are reported in Tables 1, 2 and 3, expressed considering missing data. No systemic or general complications of the infection were observed.

The majority of infections implicated wounds (45%), foreign bodies (23%) or animal bites (19%). The most frequently injured fingers were the middle (29%) and the index (27%). Mean follow-up was 4.65 weeks (95% CI = [3.53; 5.77]). 57% of patients presented no comorbidities.

Phlegmon was mostly stage I (62.5%). Six patients were treated for recurrence or osteoarticular extension: 4 (8.5%) in Group I and 2 (4.1%) in Group II, the difference being non-significant ($p = 0.6378$).

4. Discussion

Esmarch bandages should no longer be used alone as a tourniquet in limb surgery to limit intraoperative bleeding and facilitate the comfort of the surgical procedure. It has been shown experimentally that pressure with an Esmarch bandage can reach 1,000 mmHg [9]; in clinical practice, it is not possible to control this pressure, which increases the risk of neurovascular injury [10].

Instead, pneumatic tourniquets are used [3,4]. To enhance effectiveness, exsanguination is usually performed before inflation [2,11]. Exsanguination techniques include simple elevation of the limb or elevation associated with mechanical compression by manual maneuver, Velpeau stretchy band, Esmarch bandage, Rhys-Davies device or sterile Hemaclear® device. [12]. The effectiveness of various exsanguination techniques was measured by organ perfusion scintigraphy with ^{99m}Tc -labeled red blood cells in 10 volunteers [13]. The rate of exsanguination varied depending on the technique: 46% at 1 min with simple elevation, 63% with Velpeau band, and 69% with Esmarch bandage. Other authors measured the effectiveness of several exsanguination techniques using the water displacement method [14]. Exsanguination volume varied: 28mL with Rhys-Davies device, 59mL with Velpeau band, and 63mL with Esmarch bandage. Whatever the assessment technique, the best exsanguination method is the Esmarch bandage, closely followed by the Velpeau band. However, complications have been reported using the Esmarch bandage: skin shear lesions, especially in fragile patients [14], pulmonary embolism in patients

operated on in the lower limb [15,16,17,18]. Although no studies have been reported, it is clear that the best rate of blood loss is obtained with Hemaclear®, although some authors object to the cost [12]; the best cost/efficacy/safety trade-off seems to be obtained with the Velpeau band [14].

The method of exsanguination is controversial in hand surgery in infectious contexts. Some consider that mechanical exsanguination increases the risk of septic spread [1,2], although this dogma is not shared by everyone; there is no scientific evidence for or against the hypothesis of a risk of septic spread [19]. Others performed mechanical exsanguination for all patients operated on for infection during 25 years of practice, without notable complications [20]. A cadaver study on 8 upper limbs found no spread to the forearm on injection of a radiopaque fluid into the thenar and mid-palmar compartments after exsanguination of the limbs by elastic bandaging [19]. Although the present clinical series was small, with short follow-up, this was the only study refuting the dogma prohibiting mechanical exsanguination in infection.

The main study hypothesis was confirmed: the rate of revision surgery after lavage of flexor tendon sheath phlegmon with or without synovectomy was not significantly greater when mechanical exsanguination was performed before inflating the tourniquet.

5. Conclusion

To improve the comfort of the operator during the surgical treatment of digital flexor tendon sheath phlegmon, we recommend mechanical exsanguination before inflating the tourniquet to avoid continuous bleeding during the procedure.

Conflicts of interest:

Philippe Liverneaux has conflicts of interest with Newclip technics, Caresyntax and Argomedical.

None of the other authors have a conflict of interest

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Table titles

Table 1. Characteristics of 47 patients treated surgically for phlegmon of the digital flexor tendon sheath with mechanical exsanguination before inflating the tourniquet (Group I)

Table 2. Characteristics of 49 patients treated surgically for phlegmon of the digital flexor tendon sheath with simple elevation before inflating the tourniquet (Group II)

Table 3. Results of 96 patients treated surgically for digital flexor tendon sheath phlegmon with mechanical exsanguination versus simple elevation before tourniquet inflation

Table 1. Characteristics of 47 patients treated surgically for phlegmon of the digital flexor tendon sheath with mechanical exsanguination before inflating the tourniquet (Group I)

Patient (N)	Gender (F/M)	Age (year)	Comorbidity	Mechanism	Agent	Finger (1-5)	Stage (I-IV)	Revision (Y/N)	Diagnosis	Follow up (weeks)
1	F	23	Smoking	Bite	Cat	4	2	N		3
2	M	44	0	Wound	Knife	4	1	N		2
3	M	71	Diabetes	Iatrogenic	Postoperative	4	2	N		6
4	F	30	0	Bite	Cat	2	2	N		2
5	M	48	0	Bite	Cat	2	2	N		2
6	M	38	0	Wound	Glass	3	1	N		2
7	M	27	0	Wound	Crush injury	3	1	N		2
8	M	78	Diabetes	?	?	4	3	N		3
9	M	25	0	Wound	Knife	4	2	N		2
10	F	48	0	Wound	Knife	3	2	N		12
11	F	63	0	Wound	Metal	3	2	N		2
12	M	41	0	Foreign body	Plant	3	1	N		10
13	M	49	Drug addiction	?	?	2	1	N		4
14	M	33	0	Foreign body	?	3	1	N		2
15	F	62	Alcoholism	Wound	Crush injury	3	1	Y	Recurrence	2
16	F	53	0	Bite	Cat	1	1	N		3
17	F	46	0	?	?	4	1	N		2
18	F	72	0	Bite	Dog	2	1	N		12
19	M	50	0	Bite	Cat	2	1	N		5
20	M	35	Smoking	Bite	Cat	5	1	Y	Osteoarthritis	6
21	M	46	0	Wound	Glass	4	1	N		2
22	M	46	0	Foreign body	?	2	1	N		4
23	M	38	0	Wound	Metal	2	1	N		2
24	M	50	0	Wound	Metal	2	1	N		2
25	F	71	Rheumatoid Arthritis	Foreign body	Plant	2	1	Y	Arthritis	2
26	M	52	0	Foreign body	Plant	2	1	N		2
27	F	41	Smoking	Wound	Knife	1	1	N		2
28	F	47	0	Iatrogenic	Postoperative	1	1	N		24
29	M	61	0	Bite	Goat	1	1	N		2
30	F	35	0	?	?	1	1	N		2

31	F	23	0	Bite	Cat	2	1	N		4
32	M	54	0	Foreign body	Plant	4	1	N		2
33	M	27	0	Iatrogenic	Postoperative	2	2	N		36
34	M	27	Smoking	Foreign body	Plant	3	1	N		2
35	M	32	0	Wound	Metal	3	1	N		2
36	M	53	0	Wound	Tile	5	1	N		2
37	M	38	Smoking	Foreign body	Plant	4	1	N		2
38	M	60	Diabetes	Foreign body	Plant	2	1	Y	Osteitis	8
39	F	65	Hypothyroidism	Foreign body	Plant	3	1	N		3
40	F	83	Colon cancer	Bite	Dog	2	2	N		7
41	M	59	Smoking	Wound	Metal	2	2	N		6
42	F	24	0	Wound	Metal	3	1	N		2
43	F	25	0	Bite	Cat	2	1	N		3
44	M	21	Smoking	Foreign body	Plant	1	2	N		2
45	M	25	Smoking	Wound	Metal	2	2	N		2
46	F	50	Smoking	Bite	Dog	5	1	N		2
47	M	28	Smoking	Wound	Metal	3	1	N		6

F: female ; *M*: male ; *Y*: yes ; *N*: no

Table 2. Characteristics of 49 patients treated surgically for phlegmon of the digital flexor tendon sheath with simple elevation before inflating the tourniquet (Group II)

Patient (N)	Gender (F/M)	Age (an)	Comorbidities	Mechanism	Agent	Finger (1-5)	Stage (I-IV)	Revision (Y/N)	Diagnosis	Follow up (weeks)
1	M	20	0	Wound	Knife	1	1	N		3
2	F	87	Dialysis	Wound	Knife	2	2	N		2
3	F	80	0	?	?	3	3	N		6
4	M	62	Cirrhosis	Wound	Metal	3	2	Y	Recurrence	3
5	M	54	0	Foreign body	Plant	1	2	N		3
6	F	38	0	Wound	Metal	5	2	N		2
7	F	36	0	Wound	Ceramic	4	1	N		2
8	M	64	0	Wound	Metal	3	1	N		2
9	F	45	Smoking	Bite	Cat	2	1	N		2
10	M	31	Smoking	Wound	Metal	4	1	N		4
11	F	58	0	Bite	Cat	2	2	Y	Arthritis	24
12	M	61	Lymphoma	?	?	1	1	N		2
13	M	47	Diabetes	Wound	Metal	1	2	N		6
14	F	50	0	Foreign body	Plant	1	2	N		3
15	M	72	0	Foreign body	Plant	1	2	N		2
16	F	25	0	Wound	Glass	5	1	N		2
17	M	38	Smoking	Wound	Metal	3	1	N		3
18	M	62	0	?	?	1	1	N		2
19	M	59	0	Wound	Knife	3	1	N		3
20	F	66	Breast cancer	Wound	Knife	4	1	N		2
21	M	50	Diabetes	Iatrogenic	Postoperative	1	3	N		8
22	M	25	0	Bite	Cat	2	1	N		2
23	F	44	Smoking	Bite	Cat	4	2	N		2
24	F	56	Breast cancer	Foreign body	Plant	3	2	N		2
25	M	61	0	Wound	Knife	1	2	N		6
26	M	42	0	Wound	Metal	2	2	N		3
27	M	28	Smoking	Wound	Knife	3	2	N		2
28	F	43	Smoking	Wound	Knife	3	2	N		3
29	M	34	0	Wound	Metal	3	1	N		2
30	F	65	0	Foreign body	Plant	3	1	N		3
31	M	51	Gout	Foreign body	Plant	3	2	N		5
32	M	18	Smoking	?	?	2	1	N		5

33	M	63	0	Foreign body	Plant	5	1	N	2
34	M	52	0	Foreign body	Metal	1	2	N	8
35	M	45	0	Wound	Metal	3	1	N	2
36	F	42	Smoking	Bite	Dog	1	1	N	2
37	M	50	Smoking	Wound	Metal	4	1	N	12
38	F	31	Smoking	Wound	Needle	3	2	N	3
39	M	44	Smoking	Foreign body	Plant	2	2	N	3
40	M	44	Smoking, Alcoholism	Foreign body	Plant	3	1	N	3
41	M	25	0	Wound	Knife	4	1	N	3
42	F	55	0	Wound	Knife	2	1	N	9
43	M	57	0	Foreign body	Plant	5	2	N	2
44	F	44	0	Wound	Metal	1	1	N	24
45	F	52	Smoking	Wound	Metal	4	1	N	2
46	M	55	0	?	?	2	2	N	16
47	M	62	Smoking	Bite	Cat	3	2	N	2
48	M	30	0	Wound	Metal	1	1	N	8
49	F	71	Diabetes	Wound	Metal	3	1	N	6

F: female; *M*: male; *Y*: yes; *N*: no

Table 3. Results of 96 patients surgically treated for digital flexor tendon sheath phlegmon with mechanical exsanguination *versus* simple elevation before tourniquet inflation

		Group I	Group II	Difference	Significance
Mean follow-up (weeks)		4.66	4.65	0.0065	0.99
Comorbidities		18	23	5	0.39
Mechanism	Wound	17	26	9	0.15
	Bite	12	6	6	
	Foreign body	11	11	0	
Finger	1	6	13	7	0.2
	2	17	9	8	
	3	12	16	4	
	4	9	7	2	
	5	3	4	1	
Stage	I	34	26	8	0.13
	II	12	21	9	
	III	1	2	1	
Revision		4	2	2	0.64