

Limb Fasciotomy for COVID-19 Patients: Is the Chance to Cut a Chance to Cure?

Stephanie W. Holzmer, MD*
 Catherine A. Walsh, MD†
 Waseem Mohiuddin, MD*
 Frances E. Sharpe, MD‡§

Summary: Based on the findings of two consecutive cases of upper extremity compartment syndrome encountered at our institution, we hypothesize that the presence of compartment syndrome in the unstable COVID-19 patient may be associated with high mortality and low limb salvage rates. A literature search was conducted with key search terms, including “compartment syndrome, fasciotomy, COVID, and coronavirus.” Articles describing patients with a confirmed COVID-19 diagnosis who developed extremity compartment syndrome were included in our study. The primary outcome investigated was patient survival. Secondary outcomes included limb survival and limb salvage. Limb salvage was calculated in patients who survived to time of discharge, whereas limb survival was counted for all patients. We then added our two cases to the findings reported in our literature to determine current overall limb salvage and patient survival rates. Our review of the literature yielded six case reports of ten extremities that developed compartment syndrome in the COVID-19 positive patient. Overall survival was four of six patients (67%). The overall limb survival rate at the time of hospital discharge was three of 10 (30%). With the addition of our two cases, overall survival was four of eight (50%) and overall limb survival rate was three of 12 (25%). Furthermore, with inclusion of our two cases, the patient survival rate of hemodynamically unstable patients was only three of seven (43%). The development of compartment syndrome in the unstable COVID-19 patient may be a harbinger of death, and the decision to proceed with operative intervention is challenging, complex, and in some cases must prioritize life over limb. (*Plast Reconstr Surg Glob Open* 2022;10:e4454; doi: 10.1097/GOX.0000000000004454; Published online 18 July 2022.)

INTRODUCTION

Due to the novelty of the current pandemic, sequelae of the SARS-CoV2 (COVID-19) infection are continually being discovered. Though COVID-19 is traditionally known to cause a respiratory illness, other systemic manifestations have been observed, such as venous and arterial thromboembolism. In critically ill and mechanically ventilated patients, rates of venous thromboembolism are reported to be as high as 25%–30%.¹ Capillary leak syndrome has

also been observed in this patient population and may similarly be caused, in part, by global endothelial dysfunction secondary to COVID-19 infection.² Though rare, both etiologies have been the suspected cause of spontaneous extremity compartment syndrome in COVID-19 patients. The diagnosis of extremity compartment syndrome is one of the few orthopedic emergencies which require immediate operative intervention (fasciotomy) for limb salvage. However, in the unstable, coagulopathic COVID-19 patient, the decision to proceed with fasciotomy may be less clear, as these patients generally have a poor prognosis and are frequently anticoagulated. This places the patient at risk for significant hemorrhage despite the thrombotic nature of the disease.³ We present two cases of upper extremity compartment syndrome in COVID-19 patients, who were initially admitted to the hospital for respiratory distress. Both patients showed evidence of distal microthrombi in the affected limb and died within 24 hours of compartment syndrome diagnosis. These cases may add additional insight to the current body of literature describing unique manifestations of COVID-19 coagulopathy. In addition, these cases, when added to

From the *Department of Plastic and Reconstructive Surgery, Loma Linda University, Loma Linda, Calif.; †Department of Plastic Surgery, Kaiser Permanente Southern California, Ontario, Calif.; ‡Department of Orthopedic Surgery, Kaiser Permanente Southern California, Fontana, Calif.; and §Department of Orthopedic Surgery, Keck School of Medicine at USC, Los Angeles, Calif.

Received for publication April 27, 2022; accepted June 7, 2022.

Copyright © 2022 The Authors. Published by Wolters Kluwer Health, Inc. on behalf of The American Society of Plastic Surgeons. This is an open-access article distributed under the terms of the [Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 \(CCBY-NC-ND\)](https://creativecommons.org/licenses/by-nc-nd/4.0/), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

DOI: 10.1097/GOX.0000000000004454

Disclosure: The authors have no financial interest to declare in relation to the content of this article.

our review of the literature, highlight the high morbidity and mortality rate associated with the development of compartment syndrome in the unstable COVID-19 patient along with the low limb salvage rate for this same population. Based on limited available data, the presence of compartment syndrome in the unstable COVID-19 patient may be a harbinger of death, and thus, the decision to proceed with operative intervention should be made carefully, weighing the risks of each individual case.

CASE 1

A 60-year-old man with type 2 diabetes mellitus and end-stage renal disease on dialysis developed shortness of breath in the setting of COVID-19 infection. He was intubated emergently in the emergency department (ED), and subsequently went into cardiac arrest secondary to myocardial infarction. Return of systemic circulation was achieved, and he was admitted to the intensive care unit. On admission, notable laboratory values included international normalized ratio, 1.7 (0.8–1.2); lactate, 8.7 mmol/L (0.5–1.9 mmol/L); and partial thromboplastin time (PTT), 39 seconds (25–37 seconds). On hospital day 2, swelling of his left forearm and hand was noted, and an upper extremity ultrasound was ordered. Thrombus of the brachial, cephalic, and basilic veins was noted, and the patient was started on a heparin drip. He was extubated later that day as his cardiopulmonary status had improved.

On hospital day 3, vascular surgery and orthopedic surgery were consulted. The patient was noted to have a palpable brachial pulse. His radial and ulnar pulses were nonpalpable. Doppler signals were present, but multiphasic. He did not have compartment syndrome based on clinical examination at that time as compartments were soft and compressible, and he did not complain of pain, nor did he have passive pain with motion of the fingers. The presence of dorsal bullae and discoloration of the hand were noted. However, his examination evolved over the following days. By the afternoon of day 5, his hand was increasingly swollen, and hand compartments were tense. His sensation was absent in the ulnar aspect of the hand. He still did not have significant pain. Given this constellation of findings, compartment syndrome was diagnosed. After consultation with internal medicine, vascular surgery, and anesthesia, the patient underwent emergent surgical exploration with fasciotomies and extended carpal tunnel release in the operating room under local anesthesia and intravenous sedation (Figs. 1–3). The muscles were noncontractile upon fascial release. Heparin was stopped an hour and a half before surgery and resumed about 2 hours after.

On postoperative day 1, the patient had cardiopulmonary arrest. During the course of his hospital stay, it was discovered that the patient had an active “do not resuscitate” order. This was not known at the time of initial presentation. Because of this, resuscitation was not attempted and the patient died.

CASE 2

A 60-year-old man with no known medical history presented to the ED with shortness of breath and discoloration

Takeaways

Question: Is the presence of compartment syndrome in the unstable COVID-19 patient associated with high mortality and low limb salvage rates?

Findings: The survival rate for unstable COVID-19 patients who developed spontaneous extremity compartment syndrome is 43%. The limb salvage rate for COVID-19 patients who developed extremity compartment syndrome, but survived to hospital discharge, was 60%.

Meaning: Development of extremity compartment syndrome in the unstable COVID-19 patient is associated with high mortality and low limb salvage rates. As such, the decision to proceed with operative intervention is challenging, complex, and in some cases must prioritize life over limb.

of the left arm for 1 day. He was intubated in the ED emergently for treatment of respiratory compromise. Notable laboratory values included international normalized ratio,



Fig. 1. Case 1: appearance of the dorsal hand at the time of fasciotomy.



Fig. 2. Case 1: appearance of the volar hand at the time of fasciotomy.



Fig. 3. Case 1: decompression of the dorsal forearm with evidence of coagulopathy in the superficial venous system.

1.6 (0.8–1.2); lactate, 13 mmol/L (0.5–1.9 mmol/L); and partial thromboplastin time 68 seconds (25–37 seconds). On ultrasound, thrombus of the brachial, cephalic, axillary, and subclavian veins was noted. He was started on a heparin drip. Plastic surgery and vascular surgery were consulted at the time of presentation. The entire upper extremity was mottled and cold up to the shoulder. Compartments were tense. Radial and ulnar pulses were not palpable; however, Doppler signal was present. Using an arterial line pressure transducer, dorsal forearm pressure was measured to be 39 mm Hg, and the volar forearm pressure was measured to be 35 mm Hg. In consultation with the intensivist, vascular surgeon, and anesthesia provider, fasciotomy was deferred given that the patient was unstable for the operating room with a pH of 7.0 and increasing vasopressor requirement. Bedside fasciotomy was considered; however, risk of hemorrhage was significant and thought to be potentially fatal. The patient was examined approximately 6 hours later, with minimal change in examination. Pressures were measured to be 50 mm Hg in the volar and dorsal compartments. Because the patient was decompensating further, fasciotomy was deferred. The patient ultimately died 24 hours after initial presentation.

METHODS

A literature search was conducted via the use of the PubMed/Medline database with key search terms, including “compartment syndrome, fasciotomy, COVID, and

coronavirus.” Studies were independently reviewed. Case reports describing patients with a confirmed COVID-19 diagnosis who developed extremity compartment syndrome were included in our study. We specifically excluded patients who did not have compartment syndrome as the primary indication for limb salvage. The primary outcome investigated was patient survival. Secondary outcomes included limb survival and limb salvage. Limb salvage was calculated in patients who survived to time of discharge, whereas limb survival was counted for all patients. For example, limbs temporarily salvaged by fasciotomy were counted against limb survival if the patient did not survive to hospital discharge. Limb salvage was not calculated for patients who did not survive to hospital discharge. Other factors evaluated included hemodynamic instability at time of compartment syndrome diagnosis defined as requiring mechanical ventilation and/or vasopressor support, therapeutic intervention, and compartment syndrome etiology.

RESULTS

Our review of the literature yielded six case reports of ten extremities that developed compartment syndrome in the COVID-19 positive patient. One patient developed bilateral upper and lower extremity compartment syndrome secondary to capillary leak syndrome, underwent fasciotomies of both arms and legs, and then died within 24 hours.² One patient developed bilateral thigh compartment syndrome secondary to myositis and thrombotic ischemia, underwent bilateral fasciotomies, and then later required bilateral lower extremity amputations. This patient survived and was discharged to a rehab facility.⁴ One patient developed right upper extremity compartment syndrome secondary to phlegmasia cerulea dolens (PCD), underwent bedside fasciotomy, required massive transfusion for hemorrhagic shock due to bleeding at the fasciotomy site, then later died of worsening respiratory compromise. The authors report viable muscle and limb up until the time of death.⁵ One patient developed left upper extremity compartment syndrome likely secondary to capillary leak syndrome in the setting of thrombotic ischemia. This patient underwent bedside fasciotomy. Survival was not directly specified; however, the limb was presumably salvaged based on the available data.⁶ One patient developed right upper extremity compartment syndrome secondary to capillary leak syndrome and thrombotic coagulopathy, underwent fasciotomy, then required extensive soft tissue reconstruction in addition to tendon transfers for limb salvage.⁷ The last patient developed right lower extremity compartment syndrome secondary to PCD, underwent fasciotomy and mechanical thrombectomy, and then was discharged home on hospital day 70 without the need for amputation.⁸

In summary, five upper extremities and five lower extremities were affected. Varying etiologies for compartment syndrome were described, including capillary leak syndrome, PCD, and hemorrhage/thrombotic ischemia secondary to COVID-19 coagulopathy. Five patients were described as being hemodynamically unstable at the time of compartment syndrome diagnosis, and one patient

was described as hemodynamically stable at the time of diagnosis. All patients underwent emergent fasciotomy. Overall survival was four of six patients (67%) as two of the six patients died during their hospital stay. Though not directly specified, survival was presumed for one patient for the purposes of this study. Of the four patients (five limbs) who survived, three limbs were salvaged in three patients (60%). The overall limb survival rate at the time of hospital discharge according to our review was three of 10 (30%). With the addition of our two cases, overall survival regardless of surgical intervention was four of eight (50%), and overall limb survival rate was three of 12 (25%). Furthermore, with inclusion of our two cases, the patient survival rate of hemodynamically unstable patients was only three of seven (43%) (Table 1).

DISCUSSION

Systemic manifestations of the predominantly respiratory COVID-19 virus have been increasingly observed since the start of the current pandemic. Of these manifestations, both thromboembolic events and capillary leak syndrome may be caused by global endothelial dysfunction and have been implicated in the development of spontaneous compartment syndrome in the COVID-19 patient.^{2,9-11} As described in previous reports, it is postulated that COVID-19 infection may cause two distinct, yet related pathologies: thromboembolic and/or hemorrhagic coagulopathy and capillary leak syndrome.⁷ Both of these entities may cause rapid swelling, resulting in compartment syndrome of the extremities. The physical examination finding of punctate necrosis supports the theory that distal microthrombi as part of the thromboembolic COVID-19 coagulopathy may be the underlying cause of compartment syndrome in our two cases. Generally, identification of compartment syndrome is followed without hesitation by emergent fasciotomy in order for limb salvage to be achieved. However, the unique aspects of COVID-19 coagulopathy and overall poor prognosis of COVID-19 patients who go on to develop compartment syndrome make benefits of operative intervention less clear.

Most critically ill COVID-19 patients are placed on anticoagulation due to the prothrombotic nature of the disease, rendering these already unstable patients susceptible to massive hemorrhage following fasciotomy as shown in one of the cases reviewed here, without clear

benefit of undergoing operative intervention.⁵ Just before the onset of the COVID-19 pandemic, the European Society for Vascular Surgery published new guidelines for the management of acute limb ischemia that highlight the difficult decision-making process for management of patients who are critically ill.¹² This is especially true for critically ill COVID-19 patients, as the in-hospital mortality rate for these patients is significantly higher than for their COVID-19 negative counterparts (31.4% versus 5%–9%).¹³ Acute limb ischemia in these patients may be seen as the terminal event, and thus has been referred to as “agonal thrombosis.”¹² We believe that this phenomenon may be similarly applied to our patient group, with development of compartment syndrome in the unstable COVID-19 patient seen as the terminal event in these instances.

Though data in this area are lacking, due in large part to the novelty of the current pandemic, this review highlights the poor prognosis associated with development of extremity compartment syndrome in the COVID-19 positive patient, especially in the setting of hemodynamic instability. Our study demonstrates the low limb survival rate associated with development of compartment syndrome in the COVID-19 patient (25%) along with the high mortality rate (50%) found in the hemodynamically unstable subset of this population. Although our study focused on overall limb survival, successful (though temporary) limb salvage following fasciotomy was reported in one patient who later died during the course of their hospital stay.⁵ Because it is impossible to predict survival outcomes, limb salvage should be strongly considered when the risks of doing so do not prioritize limb over life. One should also consider that emergent fasciotomy in this setting does not guarantee limb salvage.

It is important to note that theoretical benefits of fasciotomy in this patient population include possible limb salvage and prevention of rhabdomyolysis and subsequent renal failure from myoglobinuria, which may play a role in life preservation for the critically ill patient.^{14,15} The risks of fasciotomy in the patient population are mainly due to significant hemorrhage necessitating large volume transfusions in the already coagulopathic and/or anticoagulated patient. Furthermore, temporary cessation of anticoagulation as an ameliorating measure, even for the surgical period, may have systemic risks for patients for whom this treatment is critical to survival. In this review, patients whose degree of hemodynamic instability would not tolerate transport to the

Table 1. COVID-19 Compartment Syndrome Outcomes

Author	Year	Extremity	Etiology	Hemodynamic Status	Comorbidities	Patient Survival	Limb Survival	Limb Salvage
Almadani et al ⁴	2020	BL LE	VM, AT	Stable	TUD	Y	N, N	N, N
Case et al ²	2020	BL UE, BL LE	CL	Unstable	HTN	N	N, N, N, N	—
Hembd et al ⁵	2020	R UE	PCD	Unstable	DM, LL	N	N	—
Hill et al ⁶	2020	L UE	CL, HTC	Unstable	HTN, DM, CHF, CKD	Y?	Y?	Y?
Bibbo ⁷	2021	R UE	CL, HTC	Unstable	—	Y	Y	Y
Gutierrez et al ⁸	2021	R LE	PCD	Unstable	HTN, TUD, DM	Y	Y	Y
					Total	4/6 (67%)	3/10 (30%)	3/5 (60%)
Case 1	2022	L UE	HTC	Unstable	DM, CKD	N	N	—
Case 2	2022	L UE	HTC	Unstable	—	N	N	—
					Total	4/8 (50%)	3/12 (25%)	3/5 (60%)

(—), nonspecified; AT, arterial thrombosis; BL, bilateral; CHF, congestive heart failure; CKD, chronic kidney disease; CL, capillary leak; DM, diabetes mellitus; HTC, hemorrhagic/thrombotic coagulopathy; HTN, hypertension; L, left; LE, lower extremity, UE, upper extremity; LL, lymphoblastic leukemia; N, no; R, right; TUD, tobacco use disorder; UE, upper extremity; VM, viral myositis; Y, yes; Y?, presumably yes.

operating room underwent bedside fasciotomy. While feasible, bedside fasciotomy may increase the risk of significant hemorrhage as hemostatic control is more difficult outside of the operating room. Furthermore, the American Red Cross has declared the first-ever blood-shortage crisis, causing clinicians to triage urgency and utility of blood product needs.¹⁶ This brings in an ethical component to our clinical scenario as the risk of hemorrhage and need for transfusion may potentially outweigh the limited benefits of fasciotomy in this patient population. Expedient surgery is critical for potential limb salvage; however, a team approach with inclusion of medical or surgical intensivists, anesthesia providers, and other subspecialists such as vascular surgery may help guide the decision process.

In a logistical sense, the healthcare workforce has experienced significant strain over the course of the pandemic, limiting the accessibility and efficiency of some treatments. The burden of needing additional personnel to transport unstable COVID-19 positive patients and to staff COVID-19 positive operating rooms is high, adding another layer of difficult decision-making to this clinical scenario. This report aims to challenge the traditional dogma that “a chance to cut is a chance to cure” when it comes to compartment syndrome in the unstable COVID-19 patient. As noted by Hippocrates more than 2000 years ago, “Ars longa, vita brevis...iudicium difficile” (Life is short, the art is long...[and] judgment difficult).

CONCLUSIONS

This report adds to the current body of literature a unique manifestation of COVID-19 coagulopathy suggesting distal microthrombi as the etiology of spontaneous upper extremity compartment syndrome in our two cases. We believe that the development of compartment syndrome in the unstable COVID-19 patient may be a harbinger of death, and the decision to proceed with operative intervention in the operating room or at bedside is challenging, complex, and in some cases, must prioritize life over limb.

Stephanie W. Holzmer, MD

Department of Plastic and Reconstructive Surgery
Loma Linda University
11175 Campus Street Suite 21126
Loma Linda, CA 92354
E-mail: stephanieholzmer@gmail.com

REFERENCES

1. Ali MAM, Spinler SA. COVID-19 and thrombosis: from bench to bedside. *Trends Cardiovasc Med*. 2021;31:143–160.
2. Case R, Ramaniuk A, Martin P, et al. Systemic capillary leak syndrome secondary to coronavirus disease 2019. *Chest*. 2020;158:e267–e268.
3. Iba T, Levy JH, Connors JM, et al. The unique characteristics of COVID-19 coagulopathy. *Crit Care*. 2020;24:360.
4. Almadani M, Shiferson A, Swearingen B, et al. Compartment syndrome secondary to viral myositis as initial presentation in COVID-19 patient. *J Vasc Surg Cases Innov Tech*. 2020;6:524–527.
5. Hembd A, Kim H, Lahsaei P, et al. Upper-extremity phlegmasia cerulea dolens with compartment syndrome in coronavirus disease 2019 sepsis [published online ahead of print May 21, 2021]. *J Hand Surg Am*.
6. Hill KL, Wu VJ, Kusumoto H, et al. Management of orthopaedic emergencies during a pandemic: compartment syndrome of the hand in a patient with COVID-19: a case report. *JBJS Case Connect*. 2020;10:e2000377.
7. Bibbo C. Reconstruction of COVID-19-related compartment syndrome with massive soft tissue necrosis. *Wounds*. 2021;33:99–105.
8. Gutierrez JR, Volteas P, Skripochnik E, et al. A case of phlegmasia cerulea dolens in a patient with COVID-19, effectively treated with fasciotomy and mechanical thrombectomy. *Ann Vasc Surg*. 2022;79:122–126.
9. Knox DB, Lee V, Leither L, et al. New-onset systemic capillary leak syndrome in an adult patient with COVID-19. *Case Rep Crit Care*. 2021;2021:8098942.
10. Iba T, Connors JM, Levy JH. The coagulopathy, endotheliopathy, and vasculitis of COVID-19. *Inflamm Res*. 2020;69:1181–1189.
11. Asakura H, Ogawa H. COVID-19-associated coagulopathy and disseminated intravascular coagulation. *Int J Hematol*. 2021;113:45–57.
12. Kahlberg A, Mascia D, Bellosta R, et al. Vascular surgery during COVID-19 emergency in hub hospitals of lombardy: experience on 305 patients. *Eur J Vasc Endovasc Surg*. 2021;61:306–315.
13. Galyfos G, Sianou A, Frountzas M, et al. Acute limb ischemia among patients with COVID-19 infection. *J Vasc Surg*. 2022;75:326–342.
14. Currie IS, Wakelin SJ, Lee AJ, et al. Plasma creatine kinase indicates major amputation or limb preservation in acute lower limb ischemia. *J Vasc Surg*. 2007;45:733–739.
15. McMahon GM, Zeng X, Waikar SS. A risk prediction score for kidney failure or mortality in rhabdomyolysis. *JAMA Intern Med*. 2013;173:1821–1828.
16. American Red Cross. Red Cross declares first-ever blood crisis amid Omicron surge. RedCross. January 11, 2022. Available at <https://www.redcross.org/about-us/news-and-events/press-release/2022/blood-donors-needed-now-as-omicron-intensifies.html>. Accessed March 6, 2022.