Found Down Extremity Compartment Syndrome Secondary to Substance Use
An Observational Multicenter Study

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Background: With the worsening opioid epidemic in America, more patients are developing found down extremity compartment syndrome (FDECS). The purpose of this study was to describe this patient population, including their presenting symptoms, laboratory test results, and clinical outcomes.

Methods: We performed a 2-center retrospective review of adult patients who developed FDECS secondary to substance use from January 2006 to December 2019. Patients were managed operatively or nonoperatively at the surgeon’s discretion. Data on patient demographic characteristics, laboratory values, hospital course, and clinical outcomes were collected from electronic medical records.

Results: In this study, 91 patients were included: 85 patients were managed operatively, and 6 patients were managed nonoperatively. Most patients were male, and the mean patient age (and standard deviation) was 37 ± 11 years. Opioids were the most common substance used. Patients managed operatively underwent a mean of 4 ± 3 surgical procedures, 44% received a skin graft, 25% developed a wound infection, and 11% underwent limb amputation. Patients managed nonoperatively did not undergo a subsequent fasciotomy or amputation. At a mean follow-up of 2.3 years, persistent weakness (66%), pain (78%), persistent sensory deficits (53%), and contractures (18%) were common.

Conclusions: Patients who develop FDECS secondary to substance use have high surgical complication rates and poor clinical outcomes. We found high rates of wound infection, revision surgical procedures, and amputation, often leaving young adults with lifelong disability.

Level of Evidence: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Acute extremity compartment syndrome (AECS) is an orthopaedic emergency. Increasing pressure within a compartment impedes blood flow and subsequently damages tissues. Although AECS is commonly associated with high-energy trauma, non-traumatic causes also exist, such as found down extremity compartment syndrome (FDECS) secondary to substance use. Patients often develop substance-related FDECS by intoxication leading to prolonged immobilization in a position that reduces blood flow to a particular muscular compartment. The ensuing compartment syndrome or rhabdomyolysis can irreversibly damage tissues and threaten the limb and life. Unfortunately, as the opioid epidemic has spread across America, FDECS secondary to substance use has become a problem more frequently encountered by orthopaedic surgeons.

AECS is often a clinical diagnosis that is made on the basis of symptoms and serial physical examinations. However, it can be challenging to make the diagnosis in patients who develop FDECS secondary to substance use because many are obtunded at the time of presentation. Objective data such as creatine kinase and intracompartmental pressure can be used as adjuncts to help to inform clinical decisions.

An expeditious surgical fasciotomy is the preferred management option for patients with AECS. Increased time to surgical intervention has been associated with increased rates of tissue necrosis, amputation, and death. However, most prior studies have focused on traumatic AECS or have had a smaller patient population at a single institution. It is unclear if the conclusions would be the same for larger populations with non-traumatic etiologies of AECS. We hypothesized that patients diagnosed with FDECS have poor clinical outcomes.

Therefore, the primary aim of this study was to comprehensively describe the patient population who...
Materials and Methods

This was an institutional review board-approved retrospective review of the electronic medical records of patients who developed FDECS secondary to substance use at 2 level-II trauma centers. The Research Patient Data Registry (RPDR) system was queried using the International Classification of Diseases (ICD) codes for “non-traumatic compartment syndrome” of the upper and lower extremities from January 2006 to December 2019.

Only patients who developed FDECS after being in a position for a prolonged period of time (found down) secondary to substance use were included in this study (Fig. 1). Patients were excluded if they were younger than 18 years of age, the etiology was not secondary to substance use, or the patient did not have any documented clinical follow-up after being discharged from the hospital.

Outcome measures assessed by retrospective chart review included limb amputation, persistent pain, persistent weakness, persistent sensory deficits, and contracture at the final follow-up. The laboratory test results at presentation to the hospitals were also extracted.

Results

Demographic Characteristics

This study identified 91 patients who developed FDECS secondary to substance use (Table I). There were 85 patients treated with fasciotomy and 6 patients treated non-operatively. The mean age was 37 years, and there were 67 male patients (74%). Substance use disorder was present in 76 patients (84%). Alcohol use disorder, major depressive disorder, generalized anxiety disorder, and hepatitis C were the other most common comorbidities (Table I).

Substances of Intoxication and Site of Compartment Syndrome

On average, there were 2 different substances used per patient. The most common substance used was opioids, in 59 patients (65%). Other commonly used substances included benzodiazepines, cocaine, cannabinoids, and alcohol (Table II).

There were 142 anatomic sites of FDECS in the 91 included patients. The forearm was the most commonly affected compartment in the operative group, in 38 patients (27%), followed by the leg in 33 patients (23%), the hand in 24 patients (17%), the
were increased. Other abnormal mean results included elevated spot glucose (141 ± 68 mg/dL), blood urea nitrogen (BUN) (26 ± 19 mg/dL), creatinine (2.2 ± 1.8 mg/dL), creatine kinase (50,604 ± 49,289 U/L), peak creatine kinase (75,940 ± 156,203 U/L), creatine kinase-myocardial band (CK-MB) (448 ± 510 ng/mL), troponin (3.4 ± 19 ng/mL), amylase (367 ± 977 U/

TABLE II Substances of Intoxication, Site of Compartment Syndrome, and Presenting Symptoms of Patients with FDECS (N = 91)

| Substances used* | 2 ± 1 |
|------------------|-------|
| Opioids†         | 59 (65%) |
| Benzodiazepines† | 35 (38%) |
| Cocaine†         | 28 (31%) |
| Cannabinoids†    | 21 (23%) |
| Alcohol†         | 19 (21%) |
| Amphetamine†     | 10 (11%) |
| Antidepressant†  | 3 (3%) |
| Antipsychotic†   | 1 (1%) |
| Hallucinogen†    | 1 (1%) |

| Body site of FDECS* (n = 142) | 1.6 ± 0.6 |
| Forearm†                    | 38 (27%) |
| Leg†                        | 33 (23%) |
| Hand†                       | 24 (17%) |
| Gluteal†                    | 19 (13%) |
| Thigh†                      | 19 (13%) |
| Arm†                        | 9 (6%) |

| Clinical symptoms† | |
|---------------------|---|
| Swollen or tense muscle compartment | 75 (82%) |
| Pain                | 72 (79%) |
| Muscle weakness     | 55 (60%) |
| Decreased sensation | 50 (55%) |
| Skin discoloration  | 26 (29%) |
| Skin blisters       | 18 (20%) |
| Paresthesia         | 15 (16%) |
| Pale and cold extremity | 14 (15%) |
| Decreased pulse     | 8 (9%) |
| Absent pulse        | 8 (9%) |

| Compartment pressures | Patients measured† | 42 (46%) |
|                       | Reading* (mm Hg)   | 48 ± 26 |

| Vital signs at presentation* | |
| Body temperature (°C)        | 37.1 ± 0.8 |
| Heart rate (beats/min)      | 96 ± 18 |
| Blood pressure (mm Hg)      | 130/75 ± 20/14 |
| Respiratory rate (breaths/min)| 19 ± 6.5 |
| Oxygen saturation           | 97% ± 2.5% |

*The values are given as the mean and the standard deviation. †The values are given as the number of patients, with the percentage in parentheses.

**TABLE I Demographic Characteristics of Patients with FDECS (N = 91)**

| Age* (yr) | 37 ± 11 |
|-----------|---------|
| Sex†      | Male 67 (74%) Female 24 (26%) |
| Medical history† | |
| Substance use disorder | 76 (84%) |
| Alcohol use disorder | 23 (25%) |
| Major depressive disorder | 27 (30%) |
| Generalized anxiety disorder | 20 (22%) |
| Bipolar disorder | 15 (16%) |
| Hepatitis C | 34 (37%) |
| Smoking | 18 (20%) |
| Hypertension | 18 (20%) |
| Homeless | 8 (9%) |
| Posttraumatic stress disorder | 8 (9%) |
| Chronic pain syndrome | 7 (8%) |
| Asthma | 5 (5%) |
| Hyperlipidemia | 5 (5%) |
| Diabetes | 5 (5%) |
| Obesity | 3 (4%) |
| Hypothyroidism | 3 (4%) |
| Other psychiatric disorders | 9 (10%) |
| Other somatic comorbidities | 26 (29%) |

*The values are given as the mean and the standard deviation. †The values are given as the number of patients, with the percentage in parentheses.

**Clinical Findings**

The most common clinical finding at the time of presentation was a swollen or tense muscle compartment, which was found in 75 patients (82%). Pain was present in 72 patients (79%), muscle weakness was found in 55 patients (60%), decreased sensation was found in 50 patients (55%), skin discoloration was seen in 26 patients (29%), skin blisters were present in 18 patients (20%), paresthesias were found in 15 patients (16%), a pale and cold extremity was observed in 14 patients (15%), a decreased pulse was found in 8 patients (9%), and the pulse was absent in 8 patients (9%) (Table II). Decreased pulses and absent pulses were only seen in patients who were treated operatively. Intracompartamental pressure was measured in 42 patients (46%), yielding a mean of 48 ± 26 mm Hg. The vital signs at presentation are outlined in Table II.

**Laboratory Test Results**

On average, the white blood-cell count (WBC), C-reactive protein (CRP) level, and erythrocyte sedimentation rate (ESR) were increased. Other abnormal mean results included elevated spot glucose (141 ± 68 mg/dL), blood urea nitrogen (BUN) (26 ± 19 mg/dL), creatinine (2.2 ± 1.8 mg/dL), creatine kinase (50,604 ± 49,289 U/L), peak creatine kinase (75,940 ± 156,203 U/L), creatine kinase-myocardial band (CK-MB) (448 ± 510 ng/mL), troponin (3.4 ± 19 ng/mL), amylase (367 ± 977 U/
patients, 37 (44%) required a skin graft and 21 (25%) developed a wound infection during their hospitalization (Table IV). The mean length of stay was 20 ± 13 days.

Outcomes
The mean length of clinical follow-up was 2.3 ± 3.2 years. Persistent weakness was seen in 60 patients (66%), persistent sensory deficit was seen in 48 patients (53%), persistent pain was seen in 71 patients (78%), contractures were present in 16 patients (18%), and 9 patients (10%) underwent an eventual limb amputation (Table IV). None of the patients treated nonoperatively required a subsequent operation. None of the patients in the study died.

Discussion
FDECS secondary to substance use is an increasingly common problem. The majority of the patients in this study were young men, which is consistent with the demographic characteristics of patients with traumatic AECS and those with substance use disorder. McQueen et al. suggested that young men are more susceptible to AECS because they have a large volume of skeletal muscle relative to a fixed compartment size. Many patients had mental health disorders, which are also common among patients who have substance use disorder. Hepatitis C, which is prevalent among patients who use injection drugs, was the most common infectious disease seen in the study patient population. The most common substance of intoxication in both study groups was opioids, consistent with the ongoing opioid epidemic. The influx of illicitly manufactured fentanyl into America has been associated with increased rates of overdose and death. Fentanyl can be 100 times stronger than morphine.

### TABLE III Laboratory Test Results*

| Test                      | Value          |
|----------------------------|----------------|
| **Blood Test Results**     |                |
| WBC (>10^9/L)              | 17 ± 8         |
| CRP (mg/L)                 | 135 ± 115      |
| ESR (mm/hr)                | 34 ± 36        |
| Hemoglobin (g/dL)          | 14 ± 2.5       |
| Hematocrit (%)             | 41.5 ± 7       |
| Platelets (>10^9/L)        | 231 ± 89       |
| Sodium (mmol/L)            | 136 ± 5.5      |
| Potassium (mmol/L)         | 4.8 ± 1.4      |
| Chloride (mmol/L)          | 99 ± 7         |
| Glucose (mg/dL)            | 141 ± 68       |
| Bicarbonate (mmol/L)       | 22 ± 5         |
| BUN (mg/dL)                | 26 ± 19        |
| Creatinine (mg/dL)         | 2.2 ± 1.8      |
| Creatine kinase (U/L)      | 50,604 ± 49,289|
| Peak creatine kinase (U/L) | 75,940 ± 156,203|
| CK-MB (ng/mL)              | 448 ± 510      |
| Troponin (ng/mL)           | 3.4 ± 19       |
| Amylase (U/L)              | 367 ± 977      |
| Total bilirubin (mg/dL)    | 0.6 ± 0.5      |
| ALT (IU/L)                 | 465 ± 1,070    |
| AST (IU/L)                 | 874 ± 1,930    |
| Prothrombin time (sec)     | 15 ± 4         |
| Partial thromboplastin time (sec) | 34 ± 21 |
| Lactate (mmol/L)           | 2.9 ± 2.2      |
| Anion gap (mEq/L)          | 15 ± 6         |
| pH†                        | 7.29 ± 0.15    |
| **Urinalysis**             |                |
| pH                         | 5.8 ± 0.7      |
| Protein (mg/dL)            | 2.7 ± 6        |
| Glucose (mg/dL)            | 2.5 ± 18.6     |
| Leukocytes (wbc/hpf)       | 0.3 ± 0.6      |
| Red blood cells (rbc/hpf)  | 13.4 ± 33      |

*The values are given as the mean and the standard deviation. †This was an abnormal test result that was lower than the standard normal range.

### TABLE IV Hospital Course and Clinical Outcomes of Patients with FDECS (N = 91)

| Outcome                        | Number (%) |
|--------------------------------|------------|
| Initial operative treatment*   | 85 (93%)   |
| Hospital course                |            |
| Rhabdomyolysis*                | 59 (65%)   |
| Acute kidney injury*           | 59 (65%)   |
| Hemodialysis*                  | 26 (29%)   |
| Surgical procedures†           | 4 ± 3      |
| Skin graft*                    | 37 (41%)   |
| Wound infection*               | 21 (23%)   |

Outcomes
- Length of follow-up (yr) 2.3 ± 3.2
- Persistent weakness* 60 (66%)
- Persistent sensory deficit* 48 (53%)
- Persistent pain* 71 (78%)
- Contracture* 16 (18%)
- Amputation* 9 (10%)

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the mean and the standard deviation.
and is often mixed with other opioids. Users are often unaware of the increased strength, putting them at higher risk for overdose, prolonged immobilization, and subsequent FDECS.

The mean number of substances of intoxication per patient was 2 in both operatively and nonoperatively treated patients in the present study. When used in combination, opioids, benzodiazepines, and alcohol can also increase sedation and decrease respiratory drive. The use of multiple substances also increases the risk of overdosing, which can also lead to prolonged immobilization and subsequent FDECS. Furthermore, opioids, benzodiazepines, and cannabinoids lower blood pressure, and opioids, benzdiazepines, and alcohol decrease respiratory drive. A lower diastolic blood pressure means that even a small increase in intracompartmental pressure could compromise blood supply to a myofascial compartment. Similarly, a diminished respiratory drive can lower oxygen blood saturation and thus decrease oxygen delivery to bodily tissues. A lower blood pressure combined with reduced oxygen saturation may put patients at increased risk for FDECS.

Pain, muscle weakness, and decreased sensation were the most common presenting clinical symptoms. Some patients in this study presented with observable skin changes, including discoloration and blistering. Signs of skin damage may suggest prolonged immobilization and should prompt clinicians to consider FDECS in obtunded patients. Pallor of the extremity, diminished arterial pulsation, and pulselessness were infrequent and late signs of FDECS and should not be relied upon for initial diagnosis.

The laboratory test results of these patients at presentation indicated an increased inflammatory response with elevated inflammatory markers such as WBC, CRP, and ESR. BUN and creatinine were also elevated, indicating renal impairment. Creatine kinase and peak creatine kinase were elevated because of muscle damage. CK-MB was elevated, which usually suggests myocardial injury; however, due to the small quantity of CK-MB muscle damage. CK-MB was elevated, which usually suggests

In conclusion, FDECS secondary to substance use is an increasingly common problem that can cause extensive morbidity in young adults. Many patients present to the hospital in an obtunded state after being found down for an unknown period of time. Clinical signs such as pain, motor and sensory deficits, and skin changes should prompt the consideration of FDECS. All extremity compartments should be examined because multiple compartments can be affected, particularly in the distal extremities. A small proportion of these patients are managed nonoperatively, but the precise criteria for the
utilization of nonoperative management remain unclear. Clinical outcomes such as persistent weakness, pain, reduced sensation, contractures, and rates of amputation were high in this patient population. Further research is warranted to better understand and improve treatments for this devastating orthopaedic condition.

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