Case Report

Acute kidney injury due to pulmonary embolism: the case for ‘congestive renal failure’

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Abstract

The development of acute kidney injury in patients with pulmonary embolism (PE) has not been well documented. We report a patient who developed acute oliguria in the setting of massive PE. Catheter embolectomy followed by ultrafiltration resulted in an immediate and dramatic improvement in urine output. Uncharacteristically, serum creatinine did not rise during the oliguric phase for several days until after embolectomy, and there were no metabolic derangements. Our observation that embolectomy and ultrafiltration helped with hemodynamics and renal perfusion despite decreased cardiac output suggests that right ventricular failure from both pressure and volume overload may have been central to this process. We review the older and recent literature in support of our observations.

Introduction

Acute kidney injury (AKI) in the setting of pulmonary embolism (PE) has not been reported. Whereas the mechanism of AKI in patients with left ventricular dysfunction is thought to be related to reduced renal perfusion as a result of diminished cardiac output [1, 2], the pathogenesis is less well understood in the setting of right ventricular dysfunction. We describe a patient who developed acute oliguria and severe edema following the occurrence of massive PE. Potential mechanisms of renal injury are discussed based on the clinical presentation and course with reference to experimental models and recent studies supporting our hypothesis.

Case report

A 64-year-old previously healthy woman with no history of diabetes or hypertension and with normal renal function was admitted to the hospital for elective resection of a left cavernous sinus meningioma. On post-operative Day 9, she became suddenly tachycardic (heart rate 100–110 beats/minute), tachypneic and developed hypoxemia. Computed tomography angiogram demonstrated large bilateral pulmonary emboli. She was started on intravenous (i.v.) heparin and an inferior vena cava filter was placed. Blood pressure (BP) transiently dropped to 82/45 mmHg for 13 min, the patient was intubated and phenylephrine and norepinephrine drips were initiated, along with aggressive IV normal saline administration. BP quickly increased but urine output gradually declined and reached a nadir of 274 mL/24 h on PE Day 3 (Table 1). IV fluids were continued despite stabilization of BP for unclear reasons. A transthoracic echocardiogram performed on the day following PE showed combined right ventricular pressure and volume overload, with a severely elevated right ventricular systolic pressure of 80–85 mmHg and severe tricuspid regurgitation. A pulmonary artery catheter showed an elevated central venous pressure (CVP) and moderately reduced cardiac index (Table 1). Interestingly, despite oliguria, creatinine remained normal as did levels of all other electrolytes. The fractional excretion of sodium (FeNa) was 0.097% and the urine sediment was acellular and without granular casts. Renal ultrasound revealed normal kidney size bilaterally and no hydronephrosis. Table 1 lists urine output, laboratory values and hemodynamic parameters in the days following the PE.

On PE Day 3, the patient had an elevated jugular venous pressure (CVP 32 mmHg), massive bilateral lower extremity edema extending to the abdominal wall and a distended abdomen with hepatomegaly. Lungs were clear to auscultation and chest radiograph showed small bilateral pleural effusions without interstitial edema. The patient underwent catheter embolectomy and thrombolysis with localized urokinase therapy. The following day, urine output increased to 1343 mL/day. Mechanical ultrafiltration (Aquadex FlexFlow Fluid Removal System; CHF Solutions, Brooklyn Park, MN) was initiated because of massive fluid volume overload, as the patient had received close to 30 L of fluids. Following initiation of ultrafiltration, there was a reduction in CVP, no change in cardiac index and a dramatic increase in urine output (Table 1). Repeat echocardiography showed a decrease in right ventricular systolic pressure to 55–60 mmHg and reduction in tricuspid regurgitation. Ultrafiltration was continued for two more days after which there was a minor increase in creatinine that returned to normal.
| PE day | –1  | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|--------|-----|----|----|----|----|----|----|----|----|----|----|
|        | UO (mL/24 h) | PE Embolectomy UF | UF | UF | UF | UF | UF | UF | UF | UF | UF |
|        | 1050 | 629 | 397 | 307 | 274 | 1343 | 4865 | 4846 | 1024 | 1205 | 1080 |
|        | I/O (mL/24 h) | (net 24 h balance) | Weight (kg) | CVP range (mmHg) | CI (L/min) | RVSP (mmHg) | BUN (mg/dL) | Creatinine (mg/dL) | Sodium (mEq/L) | Potassium (mEq/L) | Cl (mEq/L) | HCO₃⁻ (mEq/L) | Urine sodium (mEq/L) | Urine creatinine (mg/dL) | FeNa (%) | Urine sediment |
| –1     | 13 624/629 | (+ 12 995) | 65 | 10–23 (16.5) | 2 | 80–85 | 17 | 0.9 | 131 | 4.0 | 98 | 25 | 20 | 132.6 |
| 0      | 8547/397 | (+ 3088) | 74.2 | 11–31 (21) | 1.84 | 67 | 20 | 0.9 | 137 | 4.3 | 110 | 23 | 22 | 0.096 |
| 1      | 3395/307 | (+ 3751) | 85.5 | 16–28 (22) | 2.14 | 55–60 | 22 | 0.9 | 140 | 3.6 | 104 | 24 | 24 | 0.096 |
| 2      | 4025/274 | (– 1404) | 82.4 | 16–32 (24) | 2.09 | 36 | 23 | 0.8 | 139 | 4.4 | 108 | 24 | 24 | 0.096 |
| 3      | 1319/2723| (– 6150) | 73.1 | 14–23 (18.5) | 2.07 | 36 | 26 | 1.1 | 134 | 4.4 | 107 | 23 | 23 | 0.096 |
| 4      | 795/6945 | (– 3904) | 64.2 | 12–20 (16) | 2.27 | 34 | 32 | 1.4 | 135 | 3.9 | 99 | 23 | 23 | 0.096 |
| 5      | 942/4846 | (– 315) | 65.6 | 5–15 (10) | 2.27 | 29 | 28 | 1.4 | 138 | 3.1 | 103 | 26 | 32 | 0.096 |
| 6      | 709/1024 | (– 142) | 67.4 | 3–9 (6) | 2.27 | 28 | 28 | 1.3 | 137 | 3.4 | 103 | 32 | 32 | 0.096 |
| 7      | 1276/1205 | (+ 142) | 1022/1080 | 6–8 (7) | 2–10 (6) | 20 | 20 | 1.4 | 144 | 4 | 102 | 34 | 34 | 0.096 |

*Postulated pathogenesis of AKI in patients with PE and right ventricular dysfunction. UF, ultrafiltration; UO, urine output; I/O, fluid input and output; BUN, blood urea nitrogen; RVSP, right ventricular systolic pressure; CI, cardiac index; IVC, Inferior vena cava.

*CI represents average values calculated throughout the day (Fick’s method).
within a few days (Table 1). The patient remained hemodynamically stable and was discharged with a normal serum creatinine.

**Diagnosis**

To our knowledge, AKI in the setting of PE has not been previously reported. We present a case of AKI in the setting of PE, who despite oliguria, had normal electrolytes and acid–base balance. We believe that the development of oliguria in this patient was the direct result of acute severe pulmonary hypertension triggered by a PE. This is supported by the observation that urine output significantly decreased immediately following PE and by the subsequent reversal of oliguria following embolectomy. Although we cannot exclude the transient episode of hypotension following the PE as a cause for AKI, the urine sediment and the FeNa were both suggestive of a prerenal etiology and not acute tubular necrosis. Oliguria was associated with marked sodium and water retention, especially after IV fluid administration. We believe that the PE directly led to a series of hemodynamic factors resulting in renal hypoperfusion and sodium and water retention.

AKI in patients with left ventricular systolic dysfunction is thought to be related to diminished cardiac output [1, 2]. The mechanisms of AKI in the setting of right ventricular dysfunction are not well understood owing to a paucity of studies, as recently reviewed by Schrier and Bansal [3]. Low cardiac output can occur as a result of right ventricular failure due to acute severe pulmonary hypertension, which results in diminished left ventricular filling [3]. In addition, end-diastolic leftward septal shift leads to further reduction in left ventricular cavity size and output [3]. However, the reduction in cardiac index alone is unlikely to explain the marked reduction in urine output in our patient. As demonstrated by Ljungman et al. [1], usually, the glomerular filtration rate (GFR) is not severely reduced until the cardiac index drops to <1.6 L/min. Furthermore, after our patient underwent embolectomy, cardiac index did not show a significant improvement (Table 1) to explain the remarkable improvement in urine output.

Several recent studies have suggested that fluid volume overload which results in renal venous congestion rather than reduced cardiac output may be the predominant mechanism of renal dysfunction in patients with acute decompensated heart failure (ADHF). Damman et al. [4] showed that in patients with pulmonary hypertension, a higher CVP was the only independent predictor of lower renal plasma flow and GFR. Cardiac index did not correlate with GFR. In a subgroup analysis of the ESCAPE trial [5], only a higher CVP correlated with a lower GFR among all hemodynamic parameters. The same findings were reproduced by Mullens et al. [6] who, in addition, found that after treatment of ADHF, only reduction of CVP and not increased cardiac output was significantly associated with improvement in renal function and that a higher CVP predicted worsening renal function.

It is logical that in patients with right ventricular dysfunction and elevated CVP, inferior vena cava and renal vein pressures are also increased to a similar extent, which in turn, results in ‘renal congestion’, increased renal interstitial pressure and renal edema. When a certain venous pressure threshold is reached, arterial blood flow is reduced and GFR drops, particularly if cardiac output and/or systemic arterial pressure are also reduced. A body of experimental data supports this hypothesis. Winton et al. [7] showed that raising renal vein pressure >20 mmHg in the isolated perfused heart–lung–kidney model resulted in an abrupt reduction in urine output, renal blood flow and GFR. Firth et al. [8] reproduced the same results and postulated that renal venous hypertension may be the underlying mechanism of renal dysfunction and salt and water retention in patients with cor pulmonale. In 1950, Maxwell et al. [9] documented an excellent correlation between measured renal vein pressure and CVP in both patients with elevated CVP and in normal controls. Based on these studies, it is possible that renal venous hypertension is indeed important in the pathogenesis of renal dysfunction and sodium and water retention patients with right ventricular dysfunction.

In our patient, both PE and aggressive IV fluid administration resulted in a marked increase in CVP (up to 32 mmHg), which corresponded to the period of oliguria. There was an excellent correlation between improvement in urine output and reduction of CVP, but not with the changes in cardiac index (Table 1).

An additional mechanism via which right-sided cardiac dysfunction may cause renal dysfunction is raised intra-abdominal pressure (IAP) as a result of visceral edema and/or ascites. We reported a patient with cardiomyopathy whose oliguric AKI resolved following paracentesis [10]. In a recent study of patients with ADHF, high IAP predicted renal dysfunction [11]. Abdominal decompression via paracentesis or ultrafiltration resulted in improvement of IAP and renal function [12]. Aggressive IV fluid resuscitation, as in our patient, has been associated with raised IAP due to visceral edema and third spacing [10, 13]. The mechanism of renal failure associated with high IAP is thought to be due to raised renal vein pressure [14]. Even though IAP was not recorded in our patient, both the massive IV fluid resuscitation and right ventricular failure could have led to visceral edema and raised IAP.

It is interesting that in our patient, electrolyte and acid–base balance were well maintained despite oliguria. One explanation may be increased intra-renal synthesis of vasodilators such as prostaglandins, which counteract the neurohormonal mechanisms causing vasoconstriction, thereby minimizing renal ischemia [15]. It is curious that in an experimental model of increased IAP, Shenasky and Gillenwater [16] observed that tubular function was preserved despite diminished GFR and oliguria, similar to our patient.

The definitive treatment of AKI in the setting of massive PE is embolectomy, which reversed oliguria in our patient. This may have been related to improved right ventricular cardiac output, reduced CVP, reduced IAP and, consequently, reduced renal congestion. In support of this hypothesis, there was a significant improvement in urine output after initiation of ultrafiltration, perhaps reflecting a reduction in right ventricular volume overload. Recent studies support the role of mechanical ultrafiltration in patients with ADHF [17].
In summary, we postulate that in our patient, oliguria was the direct result of PE, severe pulmonary hypertension and right ventricular dysfunction. The mechanisms underlying renal dysfunction could include increased renal vein pressure and/or increased IAP and perhaps reduced cardiac output (Figure 1). Embolectomy and possibly ultrafiltration resulted in a prompt reduction of renal venous congestion and reversal of oliguria. This case challenges the current paradigm that renal dysfunction in the setting of ADHF is the result of low cardiac output alone and supports the role of venous congestion.

Conflict of interest statement. None declared.

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