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CLINICAL RESEARCH

Acute Renal Failure Following Near-Drowning

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Introduction: Acute kidney injury associated with near-drowning (ND-AKI) has rarely been reported and its incidence among survivors is unknown. A patient with AKI and urine biomarkers indicating tubular injury led us to assess the occurrence and clinical characteristics of ND-AKI and to evaluate possible causative mechanisms.

Methods: We evaluated medical records of patients rescued from near-drowning in the Mediterranean Sea and treated in a tertiary-level medical center during 2000 to 2017.

Results: Ninety-five patients with the diagnosis of near-drowning in seawater were treated. Forty-two of these patients (43%) developed ND-AKI and 17 (18%) were classified as AKI Kidney Disease: Improving Global Outcomes stages 2 to 3. ND-AKI was associated with the need for resuscitation and mechanical ventilation, with the calculated seawater volume ingestion (extrapolated from rising plasma sodium) and with the degree of acidemia, lactemia, and ventilatory failure. This series and 28 additional published cases of ND-AKI in the literature showed an overall male predisposition.

Conclusion: AKI is a common complication of near-drowning and is associated with increased in-hospital mortality. Data analysis suggests a predominant role of hypoxic tubular injury due to systemic hypoxemia in ND-AKI, combined with intense sympathetic activity (reflected by tachyarrhythmias, hyperglycemia, and relative hypokalemia) and increased oxygen expenditure for intensified distal tubular sodium transport. Androgen-related reduced renal vasodilatory capacity may explain male gender predominance.

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In the summer of 2016, we treated a patient recovering from near-drowning who developed acute kidney injury (AKI) despite swift rescue, stable hemodynamics, and adequate oxygenation throughout the hospitalization course. This unusual incidence led us to review and analyze previously reported cases of AKI following near-drowning (ND-AKI) and to perform a retrospective analysis of patients admitted with near-drowning to a tertiary-level referral hospital in Northern Israel, located near Haifa's popular beaches on the Mediterranean Sea. The aim of this study was to evaluate the incidence of AKI among survivors following near-drowning and to identify plausible mechanisms and factors predisposing to this complication. Specifically, we looked for indices suggesting hypoxic injury, likely the outcome of reduced oxygen delivery, coupled with enhanced oxygen consumption for tubular transport.

METHODS

A retrospective analysis was performed using the electronic medical record database of the Rambam Health Care Campus. Medical records of all hospitalized patients diagnosed as near-drowning at discharge during the period of January 1, 2000, to August 31, 2017, were retrieved and analyzed with approval by the institutional ethical committee. Diagnosis of near-drowning was confirmed by review of the patient history, follow-up, and discharge notes. Patients were diagnosed with ND-AKI if within the first 72 hours of their presentation the difference between highest and lowest creatinine (either ratio or absolute difference) at that period fulfilled the Kidney Disease: Improving Global Outcomes definition and staging system of AKI,[1]

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which was also used for staging of AKI severity of our patients. Patients were divided into 3 groups. The first group had no AKI. The second group was patients diagnosed with AKI stage 1, defined as a creatinine increase of at least 0.3 mg/dl or a proportional change of creatinine of 1.5 to 1.9 from baseline. The third group was patients diagnosed with AKI stage 2 to 3 (stage 2 was defined as the proportional increase in creatinine of 2.0 to 2.9 from baseline and AKI stage 3 as an increase in creatinine of at least 4 mg/dl, or a proportional change of creatinine of 3 of more from baseline).

Comorbidity data were acquired from patients' clinical notes and list of diagnoses. Patients were considered to have chronic kidney disease if it was mentioned either in the clinical notes or diagnosis list or if a previous baseline estimated glomerular filtration rate was available and lower than 60 ml/min per 1.73 m^2. Vital signs, blood gases, chemistry, and complete blood count obtained on admission were used for data assessment, as well as follow-up creatinine values during the first 120 hours following admission. Creatine phosphokinase values used for analysis were the highest values measured in the week following initial presentation. Chest radiograph interpretation was taken from the text description in the patient record. For analysis purposes, all images interpreted as edema, congestion, or diffuse or bilateral consolidations were defined as pulmonary congestion, in contrast to the images interpreted as localized consolidation. An estimation of seawater ingested and/or aspirated was performed using the Adrogue formula for changes in plasma sodium[2] corrected for changes in glucose concentration,[3] taking into account a Mediterranean Sea water salinity of 3.8%, with an average estimated weight of 70 kg used for all patients.

Urine levels of neutrophil gelatinase-associated lipocalin and kidney injury molecule 1 were determined in our index patient with commercially available enzyme-linked immunosorbent assay kits (Rapid ELISA Kit-037; Bio Porto Diagnostics, Gentofte, Denmark, and Wuhan EIAab Science, Wuhan, People's Republic of China, respectively).

Previous cases of ND-AKI reported in the English literature were traced using MEDLINE and Google Scholar. A search for an association between kidney injury and near-drowning was performed using the following keywords: renal failure, renal injury, kidney injury, immersion, drowning. Altogether, 11 such publications were traced and analyzed, including 1 series of 15 patients.[4–14]

Statistical Analysis

Data analysis was performed using R version 3.4.0 (The R Foundation). Continuous variables are presented as means and SDs. Group comparisons were performed with 1-way analysis of variance test, and between- and within-group variance of repeated creatinine measurements were assessed using 2-way analysis of variance. Tukey test was applied for post hoc comparisons. Categorical variables are presented as proportions and were analyzed using χ^2 test. To identify possible baseline predictors of AKI, linear regression analysis was performed using the difference between highest and lowest creatinine values for each patient as the dependent variable. All independent variables were analyzed using backward stepwise model selection by minimum Akaike Information Criterion to select variables for regression analysis. Variables that were missing values for more than 20% of the patients were excluded from analysis. Patients who had missing values for more than 20% of the independent variables were excluded. Missing values of continuous variables were imputed with mean values and missing values of categorical variables were imputed with most frequent value. Statistical significance was set at $P < 0.05$.

RESULTS

Index Case

A 31-year-old previously healthy man had been submerged in seawater for approximately 4 minutes before rescue and was found to be stuporous at the scene suffering from respiratory distress, a heart rate of 230 beats per minute, and an oxygen saturation of 65% on room air. Midazolam and ketamine were administered for sedation during his swift transport to the hospital and, after failed attempts of endotracheal intubation, he was oxygenated using bag mask ventilation. On arrival, wide-complex tachycardia was detected but resolved spontaneously. His blood pressure on admission was 123/76 mm Hg and his rectal temperature was 36.6°C. He remained hypoxic with copious clear respiratory secretions. He underwent intubation and sedation and was placed in a critical care facility. As shown in Table 1, laboratory evaluation revealed severe mixed respiratory and metabolic (lactic) acidosis. Potassium levels were unexpectedly low (3.3 mmol/l). Chest radiograph performed on arrival showed pulmonary edema that cleared within 10 hours. The patient remained hemodynamically stable and well-oxygenated with permissive hypercapnia. By 24 hours, he was weaned from ventilation and by 72 hours, he was fully recovered and ambulatory and was discharged, with clinically unremarkable outpatient follow-up.

However, it is noteworthy that nonoliguric AKI developed with plasma creatinine normal on admission (1.09 mg/dl) gradually rising to 2.22 mg/dl by 48 hours,

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