

## Single Case

# Acute Kidney Injury following Exposure to Formaldehyde-Free Hair-Straightening Products

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## Keywords

Acute interstitial nephritis · Acute kidney injury · Cosmetic products · Crystal nephropathy

## Abstract

Formaldehyde-free hair-straightening products are hair-smoothing solutions widely used by professional beauty salons. Formaldehyde-free hair straighteners do not technically contain formaldehyde; however, they contain other chemicals such as glyoxyloyl carbocysteine which releases formaldehyde upon contact with heat. Moreover, its by-product glyoxylate may convert to oxalate; both compounds have potential nephrotoxic effect. Here, we report a case of a 41-year-old woman who presented to the emergency room with weakness, nausea, vomiting, and stage 3 acute kidney injury (AKI) according to Kidney Disease: Improving Global Outcomes (KDIGO) acute kidney injury staging shortly after exposure to formaldehyde-free hair-straightening product; other causes of AKI were excluded such as preceding acute illness, drug history, or other nephrotoxic agent exposure. On physical examination, the patient was pale, and her vital signs were normal. The urine microscopy and serologic workup were not indicative. Kidney core biopsy revealed interstitial edema, acute interstitial nephritis, and oxalate crystal nephropathy. Kidney function completely recovered after a short course of steroid therapy. In this case, AKI was a complication caused by exposure to hair-straightening products branded as formaldehyde free but actually containing other chemical products which release formaldehyde and other toxic chemicals when heated during the straightening procedure and may cause systemic toxicity, particularly kidney injury. Different cosmetic products are widely in use, but not all are under tight regulation, and therefore, it is important to raise the awareness among both medical teams and consumers of possible adverse health effects of different cosmetic products.

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## Introduction

Nephrotoxicity is defined as kidney injury due to toxic effects of chemicals. There are various forms of chemicals and drugs that may affect renal function in various mechanisms including acute tubular necrosis (ATN), tubulopathy and electrolyte imbalance, acute interstitial nephritis (AIN), glomerular damage, crystal nephropathy, and thrombotic microangiopathy [1–3].

Formaldehyde-free hair-straightening products contain potentially toxic chemicals other than formaldehyde. One such potential substance is glyoxyloyl carbocysteine, which is composed of glyoxylic acid, cysteine, and acetic acid. Glyoxylic acid both releases formaldehyde when heated and is converted into either glycine by AGT1 (alanine:glyoxylate aminotransferase 1) or oxalate by glycolate oxidase in the human cell peroxisomes [4].

Formaldehyde is a colorless aldehyde poisonous gas at room temperature [5]. It is usually mixed with water, and when the small fraction of soluble formaldehyde reacts with water, it quickly forms methylene glycol. For every molecule of free formaldehyde, 1,820 molecules of methylene glycol are formed [6]. Methylene glycol reverts back to free formaldehyde almost immediately upon contact with air or skin. Formaldehyde is thus absorbed through skin, eyes, and inhalation, and is eliminated through the urine [7, 8]. During the hair-straightening process, high levels of formaldehyde are found in samples of air taken from beauty salons [9] and in specimens of hairstylist workers' skin [10, 11]. In the kidney, formaldehyde has been reported to cause direct cytotoxic effect resulting in acute toxic tubular necrosis [12, 13] and may also cause an immune system response leading to AIN.

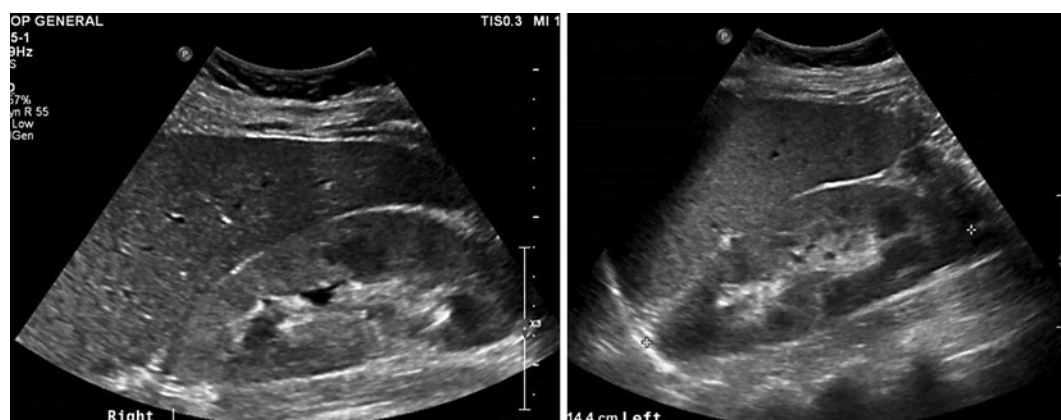
Another potential nephrotoxic component of hair-straightening products is oxalate, which is an end product of glyoxylic acid. Increased levels of oxalate promote calcium oxalate precipitation in various tissues including the kidneys, resulting in toxic injury.

## Case Presentation

A 41-year-old woman with a history of hypothyroidism and sleeve gastrectomy 5 years ago presented to the emergency department with profound weakness, nausea, and vomiting. Her symptoms began 3 days earlier, immediately after using a professional hair-straightening formaldehyde-free product in a professional beauty salon. On physical examination, the patient was pale, her vital signs were normal, heart rate was 66 bpm, blood pressure was 125/70 mm Hg, and she had no fever or respiratory distress and appeared euvolemic.

Laboratory investigations revealed a serum creatinine of 3.46 mg/dL (1 year prior to the event, Cr. value was 0.6 mg/dL) and urea 77 mg/dL, and electrolytes, liver function tests, Beta human chorionic gonadotropin ( $\beta$ -hCG), and complete blood count were normal. Blood venous gases revealed pH 7.375,  $\text{HCO}_3^-$  21 mmol/L, and base excess 3 mmol. The anion gap and serum osmolar gap were normal. Urinalysis demonstrated leukocyturia +1 without hematuria or proteinuria.

During hospitalization, urine output was normal, repeat urinalysis demonstrated leukocyturia +1 without hematuria or proteinuria, and Bence-Jones protein was negative. Urine microscopy demonstrated epithelial cells with few white blood cells without any casts or crystals. Renal ultrasound showed 14.4-cm bilateral echogenic, edematous renal parenchyma (shown in Fig. 1). A full serologic workup including hepatitis B and C, human immunodeficiency virus, syphilis, antinuclear antibody, anti-double stranded DNA, antineutrophil cytoplasmic antibody, antiphospholipid antibody (APLA) was normal except for a complement C3 level of 80 mg/dL (normal range 90–110 mg/dL).



**Fig. 1.** Kidney ultrasound demonstrates a bilateral enlarged kidney (14.4 cm) with echogenic, edematous parenchyma.

On the 4th hospitalization day, a renal core biopsy was performed. The histologic examination (shown in Fig. 2) was correlated with ATN, tubulointerstitial nephritis, and oxalate crystals. With the diagnosis of interstitial nephritis, the patient was started on prednisolone 1 mg/kg and 1 week later serum creatinine decreased to a level of 0.98 mg/dL.

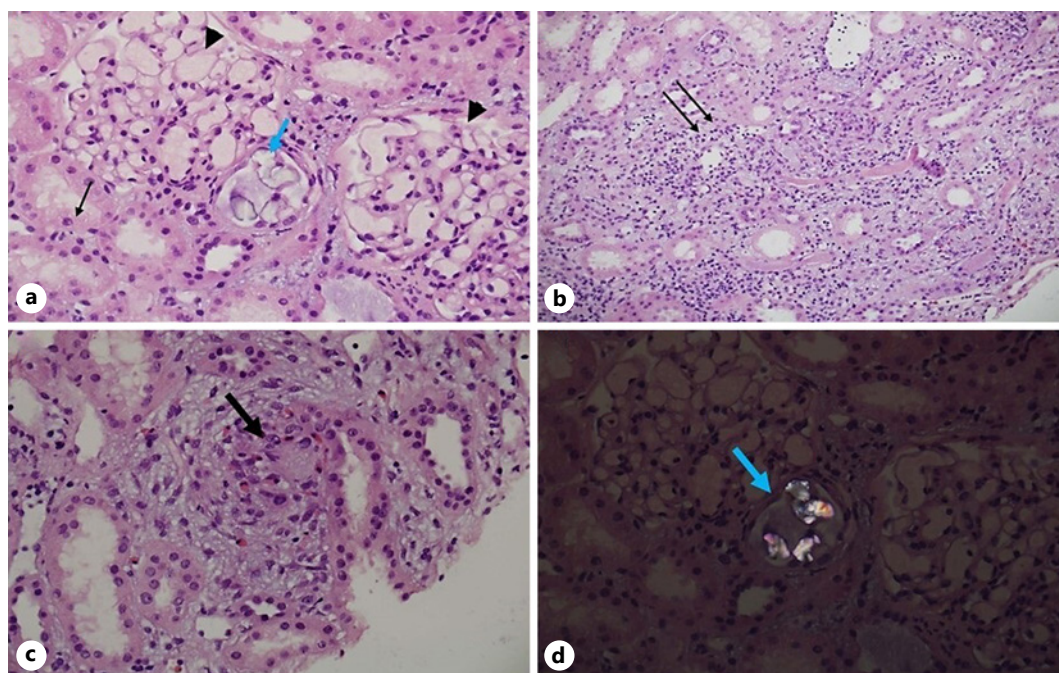
## Discussion

This study reports an unusual case of toxic and inflammatory kidney injury accompanied with oxalate deposition secondary to hair-straightening products. In a literature review, only few cases [14, 15] of acute kidney injury (AKI) following hair-straightening formaldehyde-free product exposure were reported. All cases were reported after 2019. The spectrum of kidney injury following hair straightening ranges from mild to severe kidney injury requiring renal replacement therapy. The histopathologic changes reported mainly depicted severe ATN and AIN.

Our patient presented with stage 3 AKI following hair-straightening formaldehyde-free product exposure. Other causes of AKI were excluded such as preceding acute illness, drug history, or other nephrotoxic agent exposure. Laboratory workup revealed leukocyturia +1, and ultrasonography was significant for enlarged edematous echogenic renal parenchyma. Kidney biopsy demonstrated AIN, oxalate crystal precipitation, and ATN. We speculate that the clinical presentation and the histopathologic changes directly resulted from exposure to the hair-straightening formaldehyde-free product.

In reviewing the ingredients of the specific product used in this case, it included glyoxyloyl carbocysteine, glyoxyloyl keratin amino acid, propylene glycol glycerin, phenoxyethanol, ethylhexylglycerin disodium and other collagen, surfactant, and fragrance components. We did not find evidence in the medical, pharmacological, and chemical literature that any of these substances causes AKI other than glyoxyloyl carbocysteine.

Many hair-straightening products are labeled as formaldehyde “free” but actually contain chemicals such as glyoxyloyl carbocysteine or methylene glycol which release formaldehyde and other toxic chemicals when heated, e.g., the carbocysteine hair treatment represents the combination of glyoxylic acid + cysteine + acetic acid. Glyoxylic acid contains an aldehyde functional group and glyoxylic acid behaves as an aldehyde when heating during the hair straightening process, thus releasing high levels of formaldehyde gas exceeding the capacity



**Fig. 2.** Kidney core biopsy: hematoxylin and eosin staining. **a** Glomeruli were normocellular and without signs of active glomerular disease (arrow heads), tubules showed signs of diffuse tubular injury (black arrow), and tubules contained oxalate crystals (blue arrow). **b** The interstitium showed edema associated with multifocal mixed inflammatory infiltration with multiple eosinophils and foci of tubulitis. **c** There was one epithelioid granuloma. **d** Tubules contained oxalate crystals (blue arrow).

of exposure [16]. On top of that, glyoxylic acid absorbed through the scalp may have converted to oxalic acid [17] which may precipitate in the kidney tissue. It is possible that other components such as propylene glycol may cause osmotic renal injury. In this case, serum osmotic gap was not available since it was calculated 4 days after exposure.

In conclusion, a case of severe kidney injury after exposure to hair-straightening products branded as formaldehyde free is presented. This case highlights the sensitivity of the kidney to various environmental and commercial products, some of which have not been fully characterized or identified yet.

It is important to raise the awareness among both medical teams and consumers of possible adverse health effects of different cosmetic products, including AKI and perhaps promote tighter regulation of such products.

### Statement of Ethics

Ethical approval is not required for this study in accordance with local or national guidelines. Written informed consent was obtained from the patient for publication of this case report and any accompanying images. A copy of the written consent is available.

### Conflict of Interest Statement

The authors have no conflict of interest to disclose.



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## Author Contributions

Nabil Abu-Amer, Margarita Kunin, and Pazit Beckerman: substantial contributions to the design of the case report, drafting the work, interpretation of data for the work, and revising it critically for important intellectual content. Natalie Silberstein and Sharon Mini: Substantial contributions to the design of the case report and interpretation of data for the work. All authors gave final approval of the version to be published and are accountable for all aspects of the work.

## Data Availability Statement

All data that support the findings of this study are included in this article. Further inquiries can be directed to the corresponding author.

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