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RESEARCH ARTICLE

LOW-COST POLARIZED LIGHT MICROSCOPY FOR VISUALIZATION OF OVAL FAT BODIES IN URINE SEDIMENT: A PRACTICAL DIAGNOSTIC APPROACH

Hussein Alkhadher Omar Mousa[1], and Nazeh Mohammed Al-Abd[2,*]

[1] *Scholar student, Medical laboratory sciences, Dept. of Para-Clinics, Faculty of Medicine and Health Sciences, University of Aden, Yemen*
[2] *Dept. of Para-Clinics, Faculty of Medicine and Health Sciences, University of Aden, Yemen*

***Corresponding author: Nazeh Mohammed Al-Abd; E-mail: Nazehali78@yahoo.com**

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Abstract

Oval fat bodies are lipid-laden renal tubular cells commonly observed in urinary sediment and are considered a hallmark of nephrotic syndrome. Their identification is enhanced by polarized light microscopy due to their characteristic birefringence. However, access to polarized microscopes remains limited in many low-resource laboratory settings. This study describes and evaluates a low-cost polarized light microscopy technique adapted from a previously described method for malaria pigment detection to visualize oval fat bodies and lipid droplets in urine sediment. A conventional bright-field light microscope was modified using inexpensive polarizing materials costing approximately USD 7. Urine sediment samples from patients with heavy proteinuria were examined under both conventional and polarized light. The ability of the modified system to detect birefringent lipid structures was assessed. The modified microscope successfully demonstrated classic Maltese cross birefringence in oval fat bodies, circular fat droplets, and fatty casts. Differentiation from morphologically similar urinary elements such as red blood cells, yeast, calcium oxalate crystals, and starch particles was feasible using polarized light characteristics. Low-cost polarized light microscopy provides an effective, affordable method for identifying oval fat bodies in urine sediment. This approach has significant potential to enhance diagnostic capability for nephrotic syndrome in resource-limited clinical laboratories.

Keywords: Oval fat bodies; Nephrotic syndrome; Urine sediment; Polarized light microscopy; Low-cost diagnostics.

Introduction

Urine sediment examination remains a fundamental diagnostic tool in nephrology and laboratory medicine, providing valuable insights into renal pathology [1], [2]. Among sediment findings, oval fat bodies (OFBs) are a distinctive feature and are widely regarded as a hallmark of nephrotic syndrome [3], [4]. Nephrotic syndrome is clinically characterized by massive proteinuria, hypoalbuminemia, edema, and hyperlipidemia and represents a major contributor to chronic kidney disease (CKD) burden worldwide [4–6].

Lipiduria in nephrotic syndrome results from increased glomerular permeability, allowing plasma lipoproteins to traverse the damaged glomerular basement membrane [4], [7]. Tubular epithelial cells reabsorb these lipids and process them intracellularly, leading to the formation of lipid-laden cells that detach and appear in urine as oval fat bodies [8]. These findings are closely linked to disease activity and progression [9], [10].

Lipids in urinary sediment may present as free-floating lipid droplets, oval fat bodies, fatty casts, or cholesterol crystals [11], [12]. Under polarized light microscopy, cholesterol esters exhibit characteristic Maltese cross birefringence, providing a highly specific diagnostic feature [13], [8]. This optical property is essential for differentiating lipiduria from morphologically similar urinary elements such as erythrocytes, yeast, and crystals [12], [14].

Despite its diagnostic value, polarized light microscopy is not routinely available in many laboratories, particularly in low-resource settings [15]. Recent studies have demonstrated that low-cost polarized microscopy techniques, originally developed for infectious disease diagnostics, can be successfully adapted for renal and urinary applications [16–18]. Such approaches align with global recommendations to expand access to essential in-vitro diagnostics [19]. To address this limitation, low-cost polarized light microscopy techniques originally developed for infectious disease diagnostics have been adapted for urine sediment examination [11], [18].

Materials and Methods

Study Design

This was a descriptive laboratory-based methodological study evaluating the feasibility of a low-cost polarized light microscopy technique for urine sediment examination.

Urine Sample Preparation

Fresh midstream urine samples were collected from patients with documented heavy proteinuria suspected of nephrotic syndrome. Samples were centrifuged at 500 × g for 5 minutes, and the sediment was examined using standardized urinalysis procedures [12], [13], [20]. [21].

Low-Cost Polarized Light Microscopy Setup

A conventional bright-field light microscope was modified by placing inexpensive polarizing films in a crossed orientation. This setup was adapted from previously described low-cost polarized microscopy methods [15], [16].

Microscopic Examination

Urine sediments were examined under both bright-field and polarized illumination, focusing on the identification of oval fat bodies, lipid droplets, and fatty casts. Observed birefringence patterns were compared with known polarized light characteristics of other urinary elements [22].

Results

Under conventional bright-field microscopy, oval fat bodies appeared as round to oval cells with refractile cytoplasmic inclusions. When examined under polarized light using the modified microscope, these structures exhibited classic Maltese cross birefringence, consistent with cholesterol ester content (Figure 1).

Free-floating lipid droplets and fatty casts also demonstrated classic Maltese cross birefringence under polarized light (Figure 2 and Figure 3). The polarized setup facilitated differentiation between lipid structures and other morphologically similar elements. Isomorphic red blood cells lacked birefringence, yeast cells showed no Maltese cross pattern, and calcium oxalate crystals displayed distinct crystalline birefringence rather than a symmetrical cross. Starch particles produced Maltese crosses with irregular and asymmetrical arms, allowing distinction from true lipid droplets [11], [12], [13].

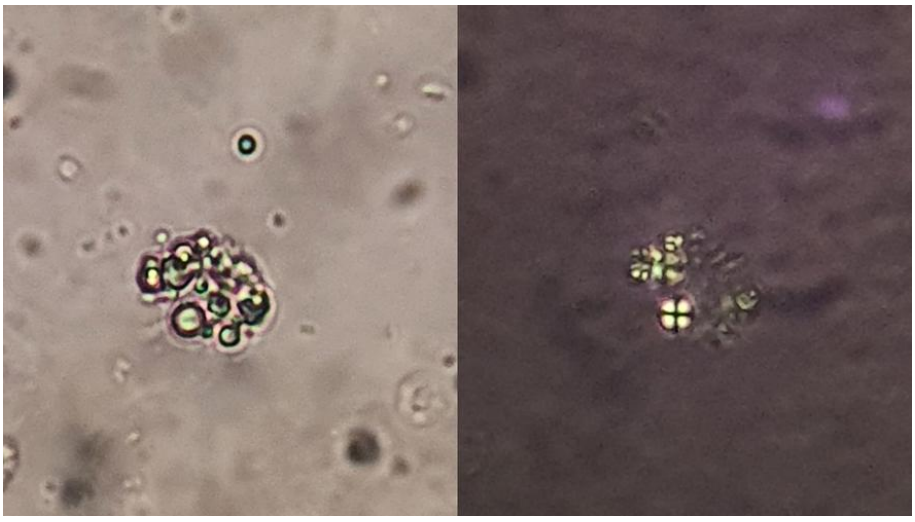

Fig. 1: Oval fat body under conventional bright-field light microscope (A) and polarized light microscope (B), (original magnification x400).

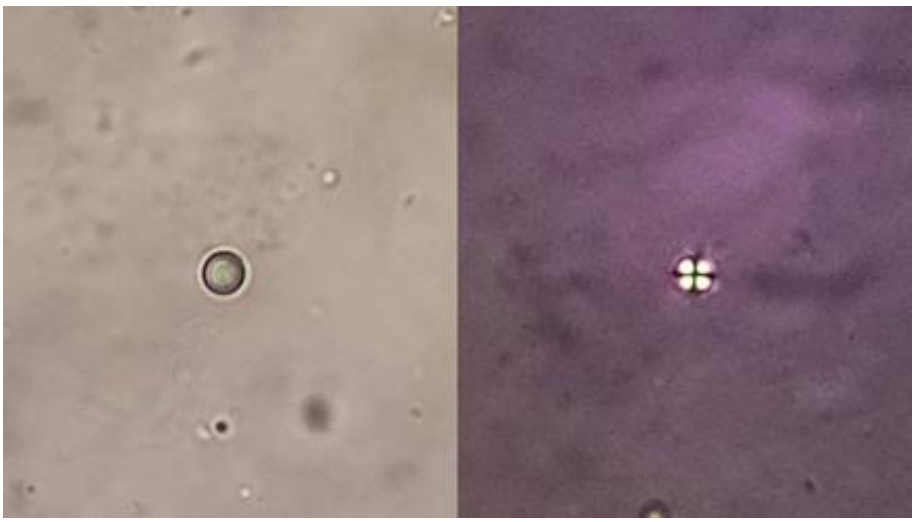

Fig. 2: Free-floating lipid droplet under conventional bright-field light microscope (A) and polarized light microscope (B), (original magnification x400).

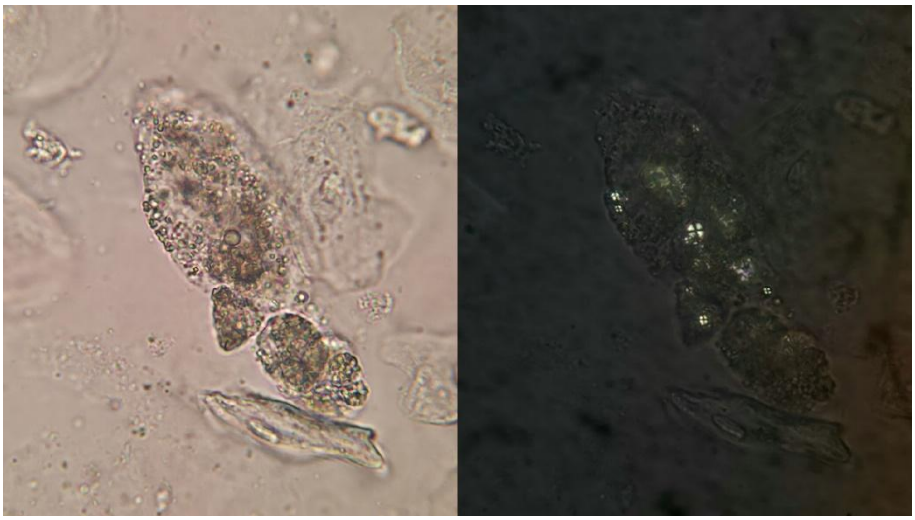

Fig. 3: Fatty cast under conventional bright-field light microscope (A) and polarized light microscope (B), (original magnification x400).

Discussion

The presence of oval fat bodies in urine sediment is strongly associated with nephrotic syndrome and reflects underlying glomerular injury and lipid metabolism disturbances [4], [7]. Urine microscopy, when combined with polarized light techniques, provides a rapid, non-invasive adjunct to biochemical testing in CKD diagnosis and monitoring [9], [23].

This study demonstrates that a simple, low-cost modification of a conventional light microscope can effectively visualize birefringent lipid structures in urine sediment. The adapted technique preserves the diagnostic advantages of polarized microscopy while overcoming financial and infrastructural barriers commonly encountered in low-resource laboratories.

Misidentification of lipid droplets remains a challenge in routine urinalysis, particularly in laboratories without access to polarized microscopy [24], [25]. The low-cost approach described here preserves diagnostic accuracy while overcoming financial and infrastructural barriers [17], [25], [26].

This approach extends the application of affordable optical diagnostic techniques and may improve nephrotic syndrome diagnosis in resource-limited settings [18], [19], [27].

Conclusion

Low-cost polarized light microscopy is a practical and effective method for detecting oval fat bodies and lipid droplets in urine sediment. This technique enhances routine urinalysis and supports nephrotic syndrome diagnosis, particularly in low-resource clinical laboratories. Its application is not limited to oval fat bodies and may extend to other birefringent urinary components.

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مقالة بحثية

المجهر الضوئي المستقطب منخفض التكلفة لتصوير الأجسام الدهنية البيضوية في راسب البول: نهج تشخيصي عملي

حسين الخضر عمر موسى[1]، و نزيه محمد العبد[2،*]

[1] طالب باحث، علوم المختبرات الطبية، قسم العلوم السريرية المساندة، كلية الطب والعلوم الصحية، جامعة عدن، اليمن
[2] قسم العلوم السريرية المساندة، كلية الطب والعلوم الصحية، جامعة عدن، اليمن

* الباحث الممثّل: نازح محمد العبد؛ البريد الالكتروني: Nazehali78@yahoo.com

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المُلخّص

تُعد الأجسام الدهنية البيضوية من الخلايا الأنبوبية الكلوية المحمّلة بالدهون، ويُعتبر وجودها في راسب البول علامة مميزة لمتلازمة النفروزي. ويُعزَّز تشخيصها باستخدام المجهر ذي الضوء المستقطب نتيجة خاصية الانكسار المزدوج المميزة لها، إلا أن توفر هذا النوع من المجاهر محدود في العديد من المختبرات ذات الموارد المحدودة. تهدف هذه الدراسة إلى وصف وتقييم تقنية منخفضة التكلفة للمجهر ذي الضوء المستقطب، تم تعديلها من تقنية مستخدمة سابقًا في الكشف عن صبغة الملاريا، وذلك لاستخدامها في إظهار الأجسام الدهنية البيضوية وقطيرات الدهون في راسب البول. تم تعديل مجهر ضوئي تقليدي باستخدام مواد استقطاب بسيطة ومنخفضة التكلفة لا تتجاوز 7 دولارات أمريكية. جرى فحص عينات من راسب البول لمرضى يعانون من بروتينية شديدة تحت المجهر الضوئي العادي والمجهر ذي الضوء المستقطب، مع تقييم القدرة على إظهار البنى الدهنية ذات الانكسار المزدوج. أظهر المجهر المعدل نمط الانكسار المزدوج المعروف بشكل "الصليب المالطي" في الأجسام الدهنية البيضوية، وقطيرات الدهون، والأسطوانات الدهنية. كما أمكن التمييز بينها وبين مكونات بولية أخرى مشابهة شكليًا مثل كريات الدم الحمراء، والخمائر، وبلورات أوكسالات الكالسيوم، وجزيئات النشا. توفر تقنية المجهر ذي الضوء المستقطب منخفض التكلفة وسيلة فعالة وميسورة لتشخيص الأجسام الدهنية البيضوية في راسب البول، مما يسهم في تحسين القدرة التشخيصية لمتلازمة النفروزي في المختبرات ذات الموارد المحدودة.

الكلمات المفتاحية: الأجسام الدهنية البيضوية؛ متلازمة النفروتيك؛ راسب البول؛ المجهر الضوئي المستقطب؛ التشخيص منخفض التكلفة.

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