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Decoy cells detected in the urine of a patient with complex karyotype Myelodysplastic neoplasms who underwent umbilical cord blood transplantation: a case report

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Abstract

Background Currently, few literature reports document cases of decoy cells in the urine of umbilical cord blood transplant patients. The majority of the literature indicates that decoy cells are frequently identified in the urine of kidney transplant recipients.

Case presentation This case report describes a patient with Myelodysplastic Neoplasms featuring a complex karyotype who underwent umbilical cord blood transplantation. Postoperative urinary cytology revealed decoy cells, and subsequent BK virus nucleic acid testing was positive. However, the routine use of antiviral drugs by the physicians led to insufficient attention to the decoy cells and BK virus, culminating in hemorrhagic cystitis.

Conclusions Urine cytology is a simple, intuitive, rapid, and cost-effective analytical method. The presence of decoy cells in the urine can serve as an indicator for infection screening and provide a clue for clinical doctors: Detection of decoy cells in urine should prompt a more vigorous antiviral response to mitigate the risk of complications like hemorrhagic cystitis.

Keywords BK virus, Decoy cells, Urine morphology analysis, Case report, Myelodysplastic neoplasms

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Introduction

The presence of decoy cells in urine, particularly alongside other clinical symptoms and laboratory findings, may indicate a BK virus infection. When decoy cells are detected in urine, it may also indicate complications related to kidney transplantation, such as BK virus-associated nephropathy. According to previous studies, the presence of polyomavirus-infected cells (decoy cells) in urine is a valuable non-invasive screening method [1]. Decoy cells detected in the urine sediment of immunocompromised patients are usually caused by uncontrolled replication of polyomaviruses in the upper urinary tract [2]. The following is a case report of a patient with Myelodysplastic Neoplasms who underwent umbilical cord blood transplantation and had decoy cells detected in the urine.

Case presentation

A 62-year-old male patient, diagnosed with Myelodysplastic Neoplasms following bone marrow aspiration three months prior, required a transplantation. He had a 17-year history of primary thrombocythemia, treated with hydroxyurea, aspirin, and regular interferon-alpha therapy. Additionally, he had a history of chronic primary (idiopathic) myelofibrosis for over 12 years, treated with ruxolitinib 10 mg twice daily.

Laboratory examination

On October 23, 2020, bone marrow pathology revealed a disparity in proliferation among bone marrow cells, with some exhibiting low proliferation and others active proliferation. Active granulocyte proliferation was observed, notably involving myelocytes and metamyelocytes. The granulocyte-to-erythrocyte ratio was essentially normal. Between 30 and 35 megakaryocytes were counted per low-power field (LPF), displaying diverse morphologies and sizes, with some aggregations observed, alongside interstitial fibrosis. This pathological feature is consistent with myeloproliferative disease with focal myelofibrotic changes.

On May 4, 2023, the complete blood count revealed a white blood cell count of 11.5×10^9/L, a hemoglobin level of 72 g/L, a red blood cell count of 2.11×10^12/L, and a platelet count of 43×10^9/L. Additionally, the C-reactive protein was measured at 9.2 mg/L.

On May 4, 2023, the bone marrow morphological description indicated an absence of myeloid granules in the smear. This was accompanied by a decrease in the number of nucleated cells and a granulocyte-to-erythrocyte ratio (G/E) of 2.31:1. Granulocytic hyperplasia was observed primarily at the myelocyte stage and earlier, alongside a reduction in granules within some granulocytic cytoplasm and the presence of Pelger-Huët anomaly. Blast cells constituted 8.0% of the cell population, exhibiting an uneven distribution. Erythroid hyperplasia was noted predominantly in the intermediate and late stages of maturation. Mononuclear cells comprised 11.5% of the total, with 1.0% being classified as immature. No megakaryocytes were identified across the slide. Platelets were either scattered or present in small clusters of 2–3.

On May 10, 2023, bone marrow karyotype analysis revealed a complex abnormal karyotype in all 20 analyzed cells: 46,XY, del(9)(p21p24),add(14)(q24),der(22)t(1;22)(q12;p11.2) [9]/46,idem, der(6)t(6;9)(p25;p13) [11]. These complex abnormal chromosome types are detected in tumor cells, which can be seen in various hemopathy, including Acute Myelocytic Leukemia (AML), Myelodysplastic Neoplasms (MDS), Myeloproliferative Neoplasms (MPN), Acute Lymphoblastic Leukemia (ALL), Non-Hodgkin Lymphoma (NHL), and Multiple Myeloma (MM). Next-generation sequencing (NGS) analysis identified mutations in DNMT3A, MPL, TET2, TP53, and U2AF1.

On May 11, 2023, bone marrow pathology revealed mildly reduced hyperplasia within the hematopoietic tissue and diminished proliferation of the granulocytic and erythroid lineages. Megakaryocyte hyperplasia was marked, characterized by over 50 cells per low-power field (LPF), exhibiting size variation, enlarged and deeply stained nuclei, nuclear heterogeneity, frequent occurrence of bare nuclei, and a tendency toward clustering. In alignment with the 2016 World Health Organization (WHO) classification system [3], the patient's myelofibrosis was categorized as MF-2, indicating moderate fibrosis. Furthermore, the degree of bone hardening observed in the bone marrow biopsy classified the patient's bone sclerosis as grade 1, corresponding to mild bone hardening.

On August 10, 2023, the laboratory results were as follows: white blood cell count 0.2×10^9/L, hemoglobin 61 g/L, red blood cell count 2.04×10^12/L, platelet count 12×10^9/L, hypersensitive C-reactive protein 109.7 mg/L, reticulocyte percentage 0.11%, and reticulocyte count 2.2×10^9/L. Urinalysis revealed trace occult blood, protein, and significantly elevated microalbuminuria (+++). Urinary sediment examination disclosed a large number of decoy cells (Fig. 1A-C). Figure 2 shows the morphology of decoy cells under a Scanning Electron Microscope(Fig. 2A-C). Figure 3 shows the morphology of decoy cells under a Transmission Electron Microscope(Fig. 3A-C).

On August 11, 2023, viral nucleic acid quantification analysis indicated a BKV DNA load of 8.90×10^8 copies/mL in urine. After August 25, 2023, repeated positive tests for respiratory syncytial virus nucleic acid and antigen suggested recurrent infections. For the detailed results of the blood and urine routine examinations, refer to Fig. 4(Fig. 4A-B).

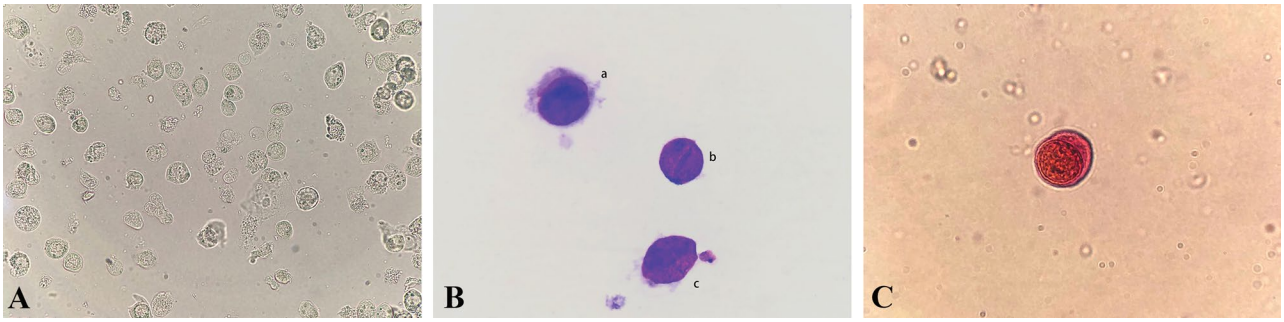

Fig. 1 (**A**–**C**) shows the morphology of decoy cells under a Optical Microscope. (**A**) shows an unstained of urinary sediment after centrifugation (magnification ×400). Many decoy cells can be seen. They are medium-sized, round, or near-round. The cytoplasm is not abundant, with a large, round, or near-round nucleus. The nucleocytoplasmic ratio is high. Some cells show dissociation of cytoplasm, while others appear as naked nuclei after complete dissociation of cytoplasm.(**B**) shows urinary sediment stained with Wright-Giemsa Staining, (magnification ×1000). The cells are medium-sized, with less cytoplasm and high nucleocytoplasmic ratio. Some cells show partial dissociation of cytoplasm (as in a and c) or appear as naked nuclei after complete dissociation (as in **B**). The nucleus is round or near-round, chromatin is loose, and nuclear staining is clearly uneven. Deep and shallow zones, as well as clear indentations (as in b), can be seen. Nucleoli are not observed. (**C**) shows urinary sediment with Sternheimer-Malbin(SM) Staining. The cells are relatively intact and similar in appearance to those stained with Wright-Giemsa Staining. Single nucleus, double nucleus, or naked nucleus decoy cells can be seen

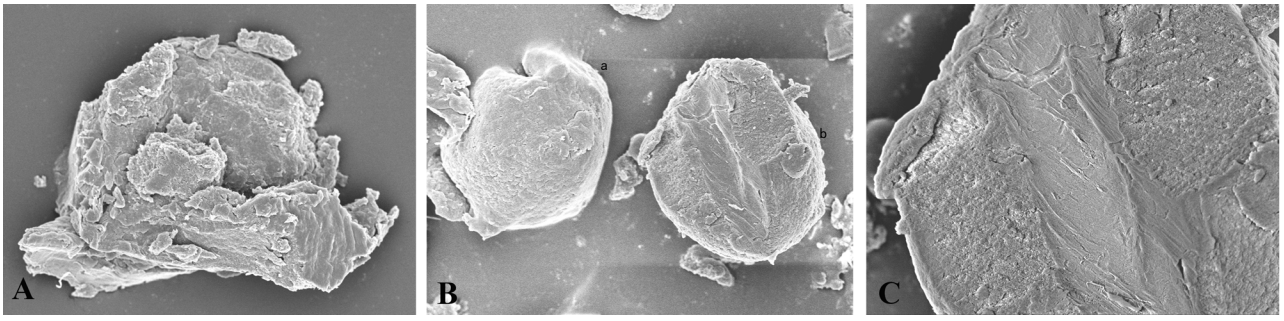

Fig. 2 (**A**–**C**) shows the morphology of decoy cells under a Scanning Electron Microscope. (**A**) (magnification ×4000), depicts a decoy cell with a rough and irregular surface and partial dissociation of cytoplasm from the nucleus. (**B**), (magnification ×5000),shows a decoy cell where the cytoplasm is almost completely dissociated, appearing as a naked nucleus. The nuclear surface is regular and neat in a, while b shows clear incisions. (**C**), (magnification ×13000), clear incisions are visible in the nucleus

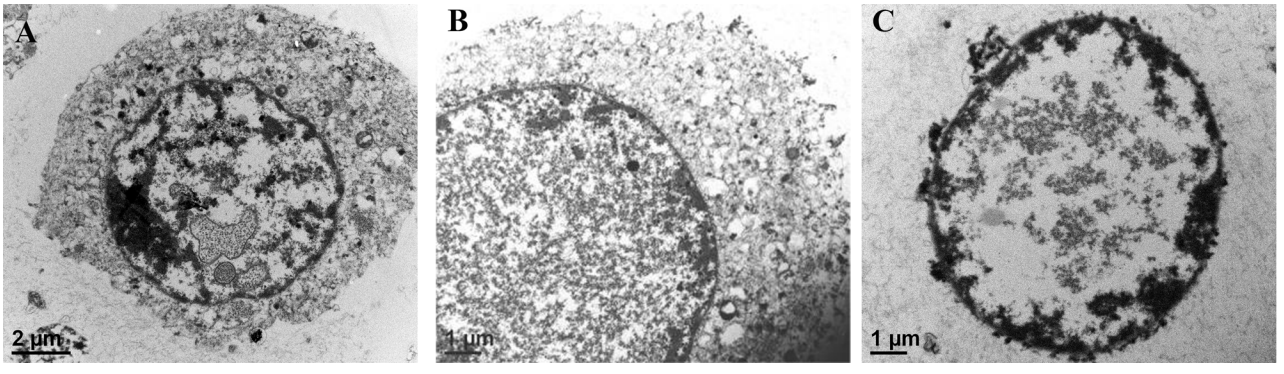

Fig. 3 (**A**–**C**) shows the morphology of decoy cells under a Transmission Electron Microscope. (**A**), (magnification ×12000), shows a cell with an incomplete cell membrane and unclear organelles in the cytoplasm, appearing as an apoptotic state. The nucleus is round with a clear nuclear membrane, but the chromatin structure is incomplete, with only some irregular heterochromatin and euchromatin remaining. The nucleus appears to be in a state of disintegration, and nucleoli are not observed. (**B**), (magnification ×15000), shows a cell with an incomplete cell membrane, no visible organelles in the cytoplasm, and vacuole-like degeneration. The nuclear membrane is clear, and the chromatin is degenerated and apoptotic, appearing homogeneous, with almost no heterochromatin and euchromatin visible. (**C**), (magnification ×15000), depicts a naked nucleus with no cytoplasm, an intact nuclear membrane, and degenerated and apoptotic chromatin, with only a small amount of chromatin remaining near the nuclear membrane

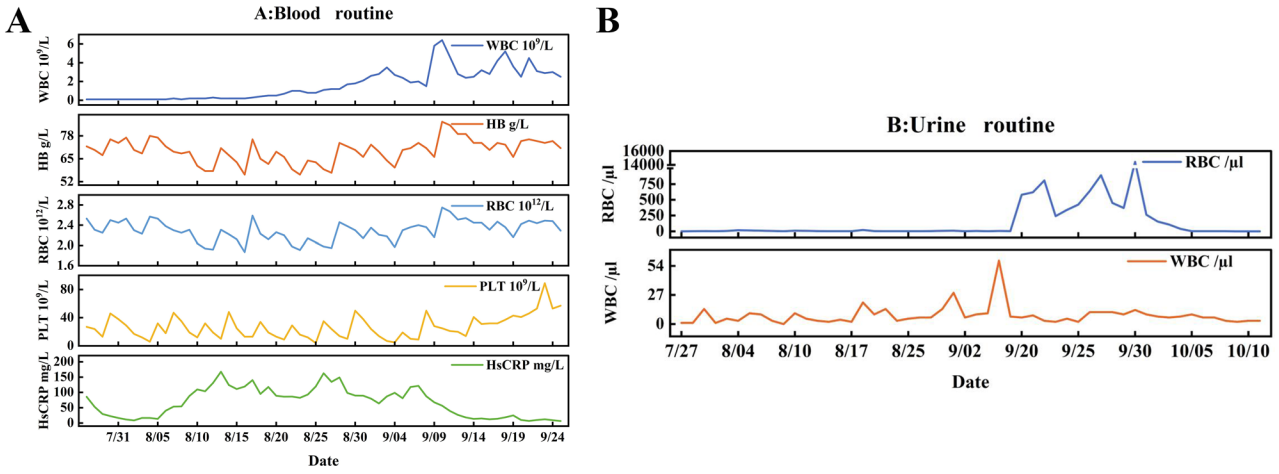

Fig. 4 (**A**–**B**) specific blood routine examination and urine routine examination. (**A**): Blood routine examination (**B**): Urine routine Examination

Diagnosis and treatment process

The patient, with a 17-year history of primary thrombocythemia, had been treated with hydroxyurea, aspirin, and regular interferon-alpha therapy. Additionally, he had a history of chronic primary myelofibrosis for over 12 years and regularly took ruxolitinib 10 mg BID. On April 29, 2023, a decline in platelet count was observed, leading to a diagnosis of Myelodysplastic Neoplasms on May 4, 2023, following bone marrow biopsy, morphological analysis, and next-generation sequencing. Subsequently, the patient was administered azacitidine 100 mg QD for days 1–7, as a demethylating immunosuppressive therapy, on May 5, May 31, and June 28.

The patient underwent pre-transplant conditioning for umbilical cord blood transplantation on July 18, 2023, comprising Total Body Irradiation (TBI) 4 Gy on day −9, Cytarabine (ARAC) 7.5 g/m^2 for 5 days, Fludarabine (FLU) 180 mg/m^2 for 5 days, and Cyclophosphamide (CTX) 2 g/m^2 for 2 days. For infection prophylaxis, the regimen included Vancomycin 4.5 g every 8 h, Micafungin 100 mg daily, and Ganciclovir 200 mg every 12 h. On day −4, the patient initiated CellCept 750 mg every 8 h and Cyclosporine 90 mg daily for graft-versus-host disease (GVHD) prophylaxis. On July 27, 2023, the patient underwent a hematopoietic stem cell transplant. The transplant involved Type A umbilical cord blood, compatible with the patient's ABO blood type, minimizing the risk of immune reactions and rejection. The total nucleated cell count (TNC) was 4.6×10^7/kg, and the CD34+cell dose was 1.9×10^5/kg. The umbilical cord blood was sourced from a certified cord blood bank.

On day 14 post-transplant, urinary cytological analysis revealed a high count of decoy cells. As the patient was already on a baseline antiviral regimen, no specific treatment for the decoy cells was initiated. On day 30 post-transplant, a positive test result for syncytial virus led to the initiation of antiviral treatment. On day 41 post-transplant, recurrent positive tests for respiratory syncytial virus (RSV) indicated a need for Ribavirin, prompting a switch to oral Lopinavir 1.5 tid. On day 55 post-transplant, hematuria suggested the possibility of hemorrhagic cystitis, and treatment with sodium bicarbonate was administered to alkalinize the urine. The patient's platelet count remained above 20×10^9/L for seven days, signifying successful platelet engraftment. On day 62 post-transplant, the patient exhibited grade 1–2 hemorrhagic cystitis, characterized primarily by microscopic hematuria and occasional dark urine, with ongoing alkalinization and hydration treatment. On day 63 post-transplant, successful engraftment of all blood cells was achieved, with mild hemorrhagic cystitis observed, leading to a treatment adjustment to Medrol 8 mg daily and Xeljanz 2 tablets twice daily. On day 67 post-transplant, an improvement in hemorrhagic cystitis was noted, with the dose of Medrol reduced to 4 mg daily and Respiratory Syncytial Virus nucleic acid testing negative. On day 74 post-transplant, the patient's hemorrhagic cystitis had essentially resolved. On day 76 post-transplant, the patient felt better and was discharged.

To mitigate the risk of transplant rejection, the patient was administered multiple immunosuppressants, including cyclophosphamide (CTX). Cyclophosphamide is widely recognized for its association with hemorrhagic cystitis as a common side effect. Dynamic monitoring of the patient's urine revealed that decoy cells persisted in the urinary sediment following the onset of hemorrhagic cystitis. Furthermore, fluctuations in urinary protein and red blood cell levels suggested compromised renal function, implicating BK virus as a potential etiology of hemorrhagic cystitis. However, immunosuppressant therapy is also known to elevate the risk and severity of hemorrhagic cystitis. See Fig. 5 for a visual representation of the patient's diagnostic and treatment course(Fig. 5).

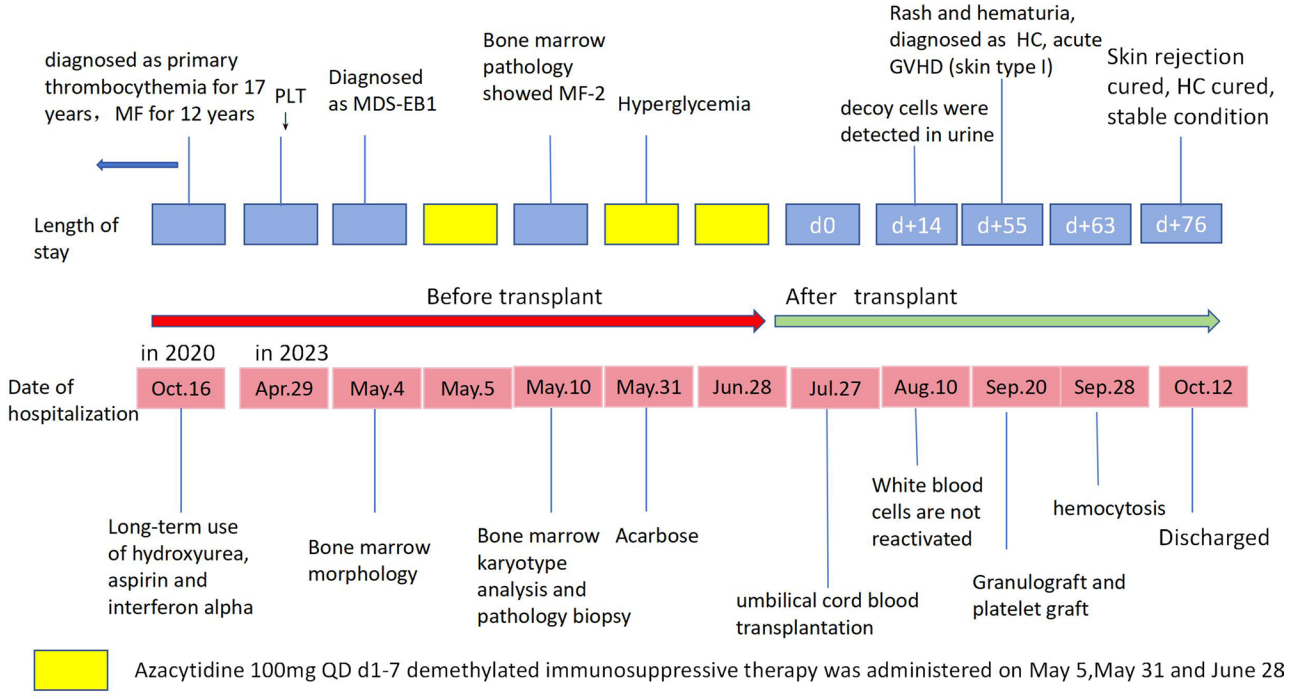

Fig. 5 The course of the patient's diagnosis and treatment

Discussion

Myelodysplastic Neoplasms (MDS), once referred to as myelodysplastic syndromes, are a group of clonal hematopoietic malignancies characterized by the presence of morphological abnormalities in the bone marrow, which often lead to symptoms such as anemia, neutropenia, or thrombocytopenia [4], usually manifested by features indicative of bone marrow failure, including inefficient hematopoiesis, dysplastic morphological development, and a reduction in peripheral blood cell counts [5]. According to the latest WHO classification standard 2022, the NGS of this patient indicated that this patient had a mutation of TP53, so according to genetics, this patient should be diagnosed as MDS-biTP53; The patient had 8% of original cells, and bone marrow pathology indicated myelofibrosis, so the patient should be defined as MDS-f based on morphology [6]. Studies have shown that patients with MDS-biTP53 and MDS-f have the shortest survival periods [7, 8].

Myeloproliferative Neoplasms (MPN) are clonal disorders originating from a single hematopoietic stem cell, leading to the overproduction of mature blood cells [9]. Over 95% of MPN cases, mutations that drive the development of the MPN phenotype are caused by somatic mutations in three genes: JAK2, CALR, or MPL [10]. According to the 2022 World Health Organization (WHO) classification criteria, MPN includes: Chronic Myeloid Leukemia (CML), Polycythemia Vera (PV), Essential Thrombocythemia (ET), Primary Myelofibrosis (PMF), Chronic Neutrophilic Leukemia (CNL), Chronic Eosinophilic Leukemia (CEL), Juvenile Myelomonocytic Leukemia (JMML), and Myeloproliferative Neoplasm, not otherwise specified (NOS) [9].

Admitted in May 2023, the patient presented with pancytopenia as revealed by the complete blood count, and the bone marrow examination was consistent with dysplastic hematopoiesis. Following a comprehensive assessment that included bone marrow chromosome morphology, histopathological evaluation, and next-generation sequencing, and after excluding other potential etiologies with similar manifestations, the patient was diagnosed with MDS.

Allogeneic hematopoietic cell transplantation (HCT) is an effective and indispensable therapy for myeloid malignancies, including AML and MDS [11]. Umbilical cord blood (UCB) is a valuable alternative donor source for allogeneic hematopoietic stem cell transplantation, it is abundant, easily harvested, simple to store, has a low immunogenicity, and possesses strong proliferative capabilities, making it an exceptionally vital alternative for transplantation as it can effectively reconstitute both the hematopoietic and immune systems [12]. The cord blood bank was initially established in 1993. Currently, approximately 5 million units of cord blood have been stored worldwide. Among them, roughly 800,000 units are housed in public cord blood banks, and over 4 million units are kept in private or family cord blood banks [13]. The HDCA/CY/TBI regimen, incorporating high-dose cytarabine (HDCA: total dose of 6–12 g/m^2), cyclophosphamide (CY:60 mg/kg administered over 2

days), and total body irradiation (TBI:10–12 Gy fractionated into 4–6 doses), has shown promising results in markedly improving patient outcomes compared to the conventional CY/TBI regimen. These enhancements are reflected in better overall survival, reduced non-relapse mortality, lower relapse rates, and mitigated adverse effects associated with cord blood transplantation, including engraftment failure, infectious complications, graft-versus-host disease, and unique toxicities attributed to HDCA [14].

Graft-versus-host disease, a major complication after hematopoietic stem cell transplantation (HSCT), is an immune response of donor cells to recipient tissue. Classic acute GVHD usually occurs within the first 100 days after transplantation, and its signs and symptoms often appear after neutrophil recovery [15]. The skin is the most common, usually starting on the face, behind the ears, palms, and soles of the feet, presenting as a erythematous maculopapular rash [16]. Calcineurin inhibitors CNI (tacrolimus and cyclosporin) combined with methotrexate (MTX) or mycophenate (MMF) remain the primary standard for HLA-matched HSCT prevention [17].

There are relatively few cures for MDS, and only a small number of patients can be cured through allogeneic hematopoietic stem cell transplantation, but the requirements are high and many complications are accompanied. In this case, the patient had unfavorable factors for transplantation: older age, previous history of bone marrow fibrosis, and multiple transfusions, all of which indicate the possibility of engraftment failure. On the 55th day after transplantation, the patient developed a scattered rash on the back and lower extremities with discoloration and pruritus, which was considered as acute GVHD (cutaneous grade 1). The patient was given Miloxone 20mgQD, MMF500mgQ8h, and cyclosporine 150mgQ12h to prevent rejection.

BK virus can cause severe hemorrhagic cystitis in hematopoietic stem cell transplant recipients [2]. Cyclophosphamide, a commonly used drug to prevent graft-versus-host disease (GVHD), is directly associated with an increased risk of BK virus (BKV) -associated hemorrhagic cystitis (HC), which not only directly damages the bladder mucosa, but also weakens the immune response against BKV and promotes the proliferation of BKV [18]. BKV-HC is a fundamental complication of hematopoietic stem cell transplantation, mainly associated with the use of cyclophosphamide, the presence of acute graft versus host disease, and donor-related factors and the research indicates that irrespective of the dosage, the administration of cyclophosphamide during the late post-transplant period significantly augments the susceptibility to BKV-HC in patients [19]. Polyomaviruses including the common BK and JC viruses, which can remain dormant in renal tubular epithelial cells and urothelial cells until the host's immune system is compromised, then they can quickly reactivate and replicate, causing death of renal tubular epithelial cells in transplanted kidneys and a significant decline or loss of function [20]. In addition to BK and JC viruses, other types of polyomaviruses may also lead to the appearance of decoy cells, but most hospitals only detect nucleic acids of BK and JC viruses, and other unknown viral subtypes and adenovirus infections may also lead to the formation of decoy cells in urine [21]. During this period, the patient's respiratory syncytial virus nucleic acid was also repeatedly positive. Whether HSV can lead to the formation of decoy cells and cause complications in patients needs further research.

In kidney transplant or bone marrow transplant recipients with immunosuppression, the reactivation of bk virus can lead to PolyomaVirus-Associated Nephropathy (PVAN) or Hemorrhagic Cystitis (HC) respectively, as the immune system cannot suppress viral replication [22]. Based on the onset time, HC can be divided usually occurs within a few days after HCT, mainly due to the toxic effects of conditioning regimens, such as cyclophosphamide, and Late-onset HC occurs after the first week, which may be related to virus reactivation, including adenovirus and BKV [23]. In a multivariate analysis, antithymocyte globulin, urine cytomegalovirus and urine BK virus were independent significant risk factors. Receiver operating characteristic (ROC) curve analysis showed that when the BK virus load was $>1\times107$ copies/mL, the risk of hemorrhagic cystitis increased significantly [24]. BK virus-associated hemorrhagic cystitis complicates 5–25% of allogeneic hematopoietic cell transplants [18]. The study also found that BK virus in the urine usually occurs before viremia and disappears after viremia disappears and The viral load in the urine is usually higher than in the blood, making the detection more sensitive [25]. A meta-analysis in 2023 showed that male, haploidentical donor, myeloablative conditioning, aGVHD(Graft Versus Host Disease), cGVHD, and CMV(cytomegalovirus) reactivation are potential risk factors for BKV-HC, so paying attention to these potential risk factors can reduce the occurrence of BKV-HC, thereby improving the quality of life and prognosis of allogeneic patients [26].

The emergence of decoy cells can predict an increased load of BK virus in the urine and has a positive predictive value of up to 90% for the presence of BK virus nephropathy [27]. In order to study the nature and structural features of decoy cells, we carried out transmission electron microscope observation (see Figs. 2 and 3). Indeed, the appearance of decoy cells is a manifestation of BK virus infecting host cells, using cell mechanisms to reproduce themselves, and eventually leading to cell death. Currently, no specific antiviral therapies are available to prevent or treat BK virus replication effectively. In

transplant recipients with ongoing BK viremia, the main intervention involves reducing immunosuppression to stimulate a BKPyV-specific immune response, without inducing rejection episodes. While the combination of mTOR inhibitors with low-dose CNIs has been proposed as a potential treatment strategy, there is insufficient evidence at present to endorse this approach widely [28].

The current guidelines suggest that virus reactivation should be monitored by regular screening of viral nucleic acids in the blood or decoy cells in urine [29]. Early detection of decoy cells in urinary sediments can alert clinicians to make corresponding treatments, which requires clinical laboratory personnel to have strong morphological diagnostic ability, and studies have confirmed that Sternberg-Malbin staining can display the good differentiation potential between decoy cells and other urinary cells [30]. However, some decoy cells may be missed when a large number of inflammatory cells are present, so monitoring decoy cells with urinary cytology combined with virus-specific immunostaining would be a good method [2]. Urinary sediment examination is an important tool in the diagnosis of renal and excretory urinary tract diseases [31]. Damaged renal tubular epithelial cells can be mistaken for bait cells. It is important to provide sufficient clinical information including clinical history, BK viremia history, and kidney biopsy to correctly detect urinary sediment [32].

This case report acknowledges several limitations. Firstly, decoy cells, characteristic of BK virus, can precipitate hemorrhagic cystitis upon viral reactivation, thereby aiding in early diagnosis and treatment. The correlation between decoy cells and hemorrhagic cystitis merits further investigation. Secondly, the findings are derived from a single-case analysis, which may limit their generalizability and applicability to a broader patient population. Future research should address the diverse scenarios encountered in stem cell transplant recipients and expand upon our observations. Furthermore, we recognize potential inadequacies in the identification and emphasis on decoy cells during urinary morphological examinations, potentially leading to misdiagnoses. Thus, we recommend that clinical laboratory staff undergo further training to accurately identify decoy cells during urinary morphological assessments, enhancing diagnostic precision. We believe heightened awareness of these limitations and their consideration in future research will bolster disease surveillance and post-transplant patient management.

Conclusion

Decoy cells are the characteristic change cells of urinary tract epithelial cells or renal tubular epithelial cells infected with BK virus, and are the early markers of BK virus-associated nephropathy (BKVAN). Hemorrhagic cystitis is one of the most common complications after allogeneic hematopoietic stem cell transplantation, which is related to viral infection, graft-versus-host disease (GVHD) and immunosuppressant use. In patients following kidney transplantation and hematopoietic stem cell transplantation (HSCT), BK virus reactivation can lead to hemorrhagic cystitis, and detection of decoy cells helps in early diagnosis and treatment. It indicates that the presence of decoy cells is transplant-related rather than specific to kidney transplantation.

Timely antiviral treatment guidance can be provided to clinicians by early detection and monitoring of decoy cells in transplant patients' urine using appropriate methods. Also, the ability of clinical laboratory personnel to recognize the morphology of decoy cells is inadequate. In urinary cytology samples, epithelial cells that harbor polyomavirus inclusion bodies are termed "decoy cells", and they exhibit distinctive features such as enlarged nuclei, homogenously stained alkalophilic nuclear inclusions, and ground-glass chromatin patterns. Pathologists must distinguish these cells to avoid misclassifying them as cancerous. Through this paper, laboratory personnel can deepen their learning of the morphological identification ability and clinical significance of decoy cells.

Abbreviations

MDS	Myelodysplastic Neoplasm/Myelodysplastic Syndromes
RSV	Respiratory Syncytial Virus
BKV	BK Virus
RBC	Red Blood Cell
WBC	White Blood Cell
HsCRP	Hypersensitive C-reactive protein
PLT	Platelets
HBG	Hemoglobin
CTX/CY	Cyclophosphamide
HDCA	High-dose cytarabine ARAC: Cytarabine
FLU	Fludarabine
PVAN	Polyomavirus-associated nephropathy
HC	Hemorrhagic Cystitis
ROC	Receiver operating characteristic
GVHD	Graft Versus Host Disease
CMV	Cytomegalovirus
UCB	Umbilical Cord Blood
TBI	Total Body Irradiation
WHO	World Health Organization
HCT	Hematopoietic Cell Transplantation
MPN	Myeloproliferative Neoplasms
CML	Chronic Myeloid Leukemia
PV	Polycythemia Vera
ET	Essential Thrombocythemia
PMF	Primary Myelofibrosis
CNL	Chronic Neutrophilic Leukemia
CEL	Chronic Eosinophilic Leukemia
JMML	Juvenile Myelomonocytic Leukemia
NOS	Myeloproliferative Neoplasm, not otherwise specified
TNC	Total Nucleated Cell
CNI	Calmodulin Inhibitors
MMF	Mycophenate
G/E	Granulocyte To Erythrocyte Ratio
LPF	Low-power Field (LPF)
AML	Acute Myelocytic Leukemia
MPN	Myeloproliferative Neoplasms
ALL	Acute Lymphoblastic Leukemia
NHL	Non-Hodgkin Lymphoma

MM Multiple Myeloma

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Author contributions
Yuli Zhou was in charge of case data collection, related literature collection and preparation of experimental reagents. Siqi Zhu was in charge of paper writing，literature retrieval and submission. Huanli Fang was in charge of morphological examination, and electron microscope experiment operation. Fuxian Zhou was in charge of language polishing and technical guidance for submission. Juan Jin is responsible for the guidance and revision of the paper.

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Data availability
The datasets generated and analysed during the current study are available in the [NCBI] database repository, [PRJNA1173101] (https://dataview.ncbi.nlm.nih.gov/object/PRJNA1173101?reviewer=tbi0j26uk7a1neau8ijulnpehq).

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Hangzhou First People's Hospital (Ethics approval number: ZN-2024369-01) and informed consent has been obtained from the patient prior to analysis.

Clinical trial number
Not applicable.

Consent for publication
Informed consent has been obtained from the patient prior to analysis, for the case presentation.

Competing interests
The authors declare no competing interests.

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