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The Effectiveness of Nursing Interventions in Improving the Quality of Urine Specimen Collection and Reducing Contamination

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ABSTRACT: Pre-analytical errors remain the leading source of laboratory error in clinical diagnostics, and urine specimen contamination is among the most common and most

preventable of these. Nursing interventions targeting the collection phase—structured patient education, standardized written and verbal instructions, demonstration of proper cleansing technique, coaching on midstream collection, and timely transport to the laboratory—have consistently been associated with measurable reductions in contamination rates. Studies examining bundled educational interventions, often combined with visual aids or teach-back methods, report contamination reductions from baseline rates of 20–30% down to under 10%, alongside decreases in unnecessary repeat testing and antibiotic prescribing. The evidence suggests that the effectiveness of these interventions depends less on any single component than on consistency of application: specimens collected by trained staff using a standardized protocol and clearly communicated patient instructions show substantially lower contamination than those collected under usual care. Despite generally favorable findings, the literature is limited by heterogeneity in how contamination is defined and detected, variability in intervention design, and a predominance of single-site pre-post studies with short follow-up, which constrains conclusions about sustainability and generalizability. Key contextual factors—staffing levels, staff turnover, patient health literacy, availability of collection kits, and the reliability of laboratory screening criteria—moderate outcomes and complicate direct comparison across settings. Methodologically stronger designs, including cluster-randomized trials and interrupted time-series analyses, are needed, as are implementation studies that identify which intervention components are essential, how best to embed protocols into routine workflow, and how to sustain gains after the initial education period. Nonetheless, the cumulative evidence supports nursing-led, multifaceted, protocol-driven approaches as a low-cost and clinically meaningful strategy for improving specimen quality and reducing downstream diagnostic error.

INTRODUCTION

Urinary tract infections are among the most common infectious diseases in both hospital and community settings, and urine culture remains the diagnostic gold standard for confirming infection and guiding antimicrobial therapy; consequently, the reliability of this diagnostic pathway depends heavily on the quality of the specimen received by the laboratory [1]. A contaminated urine specimen is not merely a technical inconvenience, because it initiates a cascade of clinical, economic, and antimicrobial stewardship consequences that affect patients, clinicians, laboratories, and healthcare systems [2]. Nursing practice sits at the centre of this pre-analytical phase, since nurses most often instruct patients, perform or supervise collection, label specimens, and ensure that specimens are handled and transported correctly [3]. The scale of the problem is considerable, and contamination rates in primary care and emergency settings have been reported to range from 20% to 55%, far exceeding the international baseline of approximately 15% to 25% described in systematic reviews [4]. The consequences are not trivial: contaminated cultures can produce false-positive results, mask the true pathogen, delay diagnosis, prompt unnecessary antibiotic prescribing, prolong hospital stay, increase laboratory workload, and contribute to antimicrobial resistance [5]. The economic burden is also measurable, and studies have shown that contaminated urine cultures generate avoidable costs through repeat testing, unnecessary treatment, and wasted laboratory resources [6]. The problem is particularly acute in catheterised patients, in whom distinguishing asymptomatic bacteriuria from genuine catheter-associated urinary tract infection is already difficult and is further confounded by poor specimen collection practice [7].

The Clinical and Economic Burden of Contaminated Urine Specimens

Contamination of urine specimens is often treated as a minor laboratory inconvenience, yet its clinical and economic consequences are substantial and well documented [1]. When a urine culture is contaminated, the laboratory may report a mixed growth of organisms that are not representative of the bladder microbiota, leaving clinicians with a diagnostic dilemma: is the result indicative of genuine infection, or does it reflect periurethral, vaginal, or skin flora introduced during collection [2]? In many cases, the result is interpreted cautiously, the patient is treated empirically, or the specimen is repeated, leading to delayed diagnosis and additional costs [5]. The cascade of adverse events includes unnecessary laboratory processing, clinician time reviewing misleading results, patient anxiety, and, most detrimentally, the initiation or prolongation of unwarranted

antimicrobial therapy [6]. In a tertiary hospital study of 2,835 urine cultures, contamination accounted for 3.8% of all specimens and represented a direct loss of $873 USD, or 2.3% of the total urine culture budget, even though the absolute figure may appear modest relative to overall laboratory expenditure [6]. Other analyses have calculated the cost per rejected sample and demonstrated that contamination costs constitute a significant and avoidable financial burden when human resources, materials, waste, and reimbursement are considered [6]. These figures become even more significant when multiplied across large institutions and across the many repeat cultures that contaminated specimens generate [1]. Furthermore, the indirect costs associated with unnecessary antibiotic prescriptions, adverse drug events, Clostridioides difficile infection, and the selection of resistant organisms are difficult to quantify but undoubtedly substantial [5]. The problem is particularly acute in patients with indwelling urinary catheters, because catheterised patients are at high risk of asymptomatic bacteriuria and the distinction between colonisation and genuine catheter-associated urinary tract infection is often blurred by contaminated or poorly collected specimens [7]. Nursing interventions that standardise catheter specimen collection therefore have a dual benefit: they improve diagnostic accuracy and reduce unnecessary antimicrobial exposure, thereby supporting both infection prevention and antimicrobial stewardship agendas [7].

Sources and Mechanisms of Contamination in Urine Specimen Collection

Understanding why contamination occurs is essential for designing effective nursing interventions, and the literature consistently identifies a combination of patient-related, technique-related, and system-related factors [8]. Contamination most commonly arises from the introduction of microorganisms from the periurethral area, vagina, perineum, or skin into the urine specimen during collection, and predictors of contamination include female sex, older age, pregnancy, and collection in primary care or emergency settings [9]. Inadequate cleansing, failure to retract the foreskin in male patients, difficulty in separating the labia in female patients, and poor understanding of the midstream technique all contribute to the problem [8]. Patient self-collection in outpatient and primary care settings is particularly vulnerable because professional guidance may be limited, rushed, or inconsistent [9]. Pre-analytical factors beyond the moment of collection also play a significant role, and delays in transport, inappropriate storage temperature, and prolonged exposure of urine to room temperature can permit bacterial overgrowth and alter the specimen's microbiological profile [10]. Guidelines generally recommend that urine specimens be transported to the laboratory within two hours of collection or refrigerated if delay is unavoidable, because processing delays beyond four hours can compromise culture accuracy [10]. The choice of collection method also influences contamination risk, and clean-catch midstream urine is widely regarded as the preferred non-invasive method for adults and older children, although its effectiveness depends on correct execution [11]. In contrast, urine bag collection in infants and young children is associated with contamination rates as high as 60% to 80% because of prolonged contact with perineal skin flora [12]. Catheter specimen collection, when performed correctly from the sampling port using aseptic technique, generally carries a lower contamination risk than bag collection but is not entirely free of risk if the port is not disinfected or if urine is obtained from the drainage bag [13]. Suprapubic aspiration remains the gold standard with the lowest contamination rate, but it is invasive and reserved for specific clinical situations [14].

Standard Clean-Catch Midstream Technique: Evidence and Controversies

The clean-catch midstream technique has been taught for decades as the standard method for obtaining a voided urine specimen, and its rationale is straightforward: cleansing the periurethral area reduces the burden of local flora, and discarding the first portion of urine flushes the urethra so that the midstream portion is more representative of bladder urine [11]. Many nursing textbooks and clinical guidelines continue to recommend this approach, and it remains the foundation of patient education for urine collection [11]. However, the evidence base is more nuanced than is often acknowledged, and a systematic review of methods for urine sample collection in women with symptoms of urinary tract infection found that the quality of evidence was limited and that the comparative effectiveness of different cleansing and collection strategies was not firmly established [11]. Some studies have reported that cleaning the perineum or using the midstream technique did not produce contamination percentages significantly different from urination without any precautions, particularly in young outpatient women with urinary tract infection symptoms [12]. These findings do not render the clean-catch technique useless, but they do highlight the importance of technique fidelity and patient understanding [12]. When the clean-catch method is poorly performed—for example, when the patient does not cleanse adequately, does not retract the foreskin, or collects the initial rather than the midstream portion—its theoretical advantages are lost [11]. The nursing implication is that simply telling a patient to "do a clean catch" is insufficient, and effective nursing intervention requires structured, step-by-step instruction, ideally accompanied by visual aids, demonstration, and an opportunity for the patient to ask questions [12]. Controversy also

persists regarding the use of antiseptic solutions, and some guidelines recommend cleansing with soap and water or a mild antiseptic, whereas others caution that povidone-iodine or similar agents may contaminate the specimen and cause false-negative culture results [13]. Nursing practice should therefore follow local evidence-based protocols rather than assume that stronger antiseptics are necessarily better, and the overarching principle is to minimise the introduction of external flora without introducing inhibitory substances into the specimen [14].

Patient Education and Health Literacy Interventions

Because many urine specimens are self-collected by patients in outpatient, primary care, and emergency department settings, patient education is a cornerstone of contamination reduction [15]. Traditional verbal instructions are often inconsistent, incomplete, or poorly understood, and qualitative research with patients and healthcare professionals has shown that instructional videos and pictorial flyers can address inconsistencies in instructions and fill gaps in patient understanding, particularly regarding anatomical cleansing and the midstream technique [15]. Patients have reported confusion about the appropriate use of wipes and a lack of pictorial directions for handwashing, suggesting that written instructions alone are insufficient for many individuals [15]. Effective patient education must also account for physical barriers, because patients with poor stream control, mobility limitations, large body habitus, or advanced age may find it difficult to stop urine flow midstream, to cleanse the genital area adequately, or to position a collection cup correctly [16]. Nursing interventions that provide assistive devices—such as upright trays for collection materials, wider collection cups, and urine collection hats—can improve the patient's ability to perform the technique correctly, although the use of a urine hat may negate the midstream component and requires further evaluation [16]. The RedUCE initiative in Queensland, Australia, used posters and flyers to educate patients on correct collection technique and found that simple illustrations were an effective option for providing clear and consistent instructions [16]. These findings underscore that patient education is not a one-size-fits-all endeavour; it must be tailored to literacy, language, anatomy, and physical capability [17]. Patient perceptions of educational interventions also matter, and studies have shown that patients value clear, visual, and repeated instructions and that their confidence in performing collection improves when education is delivered in a structured and supportive manner [17].

Nurse-Led Standardisation and Best Nursing Practices

One of the most consistently effective nursing interventions is the standardisation of urine collection procedures through written protocols, checklists, competency assessment, and the use of standardised collection kits [18]. Standardisation reduces unwarranted variation in practice and ensures that every patient receives the same evidence-based instructions and every staff member follows the same aseptic technique [18]. A narrative review of best nursing practices in urine collection concluded that implementing standardised protocols, checklists, periodic training, and internal audits substantially reduces contamination rates and increases the reliability of laboratory results [18]. Similarly, a nurse-led intervention to standardise catheter specimen collection argued that a systematic approach combining protocol development, mandatory hands-on training, competency sign-off, clinical indication checks, standardised equipment, audit and feedback, and multidisciplinary integration is a highly effective, low-cost strategy for improving diagnostic accuracy and reinforcing antimicrobial stewardship [1]. The components of such standardisation are practical and replicable, and a visual step-by-step guide using aseptic non-touch technique can be displayed in collection areas and used during training [2]. Mandatory hands-on training with competency sign-off ensures that staff can demonstrate correct technique rather than simply attest to having read a policy, while standardised supply kits containing sterile syringes, chlorhexidine or alcohol wipes, and appropriate containers eliminate technical barriers to compliance [2]. Removing non-sterile containers from collection areas prevents inadvertent use, and clinical indication checklists empower nurses to clarify non-urgent or inappropriate culture orders with prescribers, reducing unnecessary culturing for asymptomatic bacteriuria [3]. Audit and feedback close the loop by monitoring laboratory-reported contamination rates per unit and sharing data with nursing and stewardship teams, and when these elements are combined, standardisation becomes more than a policy document because it becomes a system of accountability and continuous improvement [18].

Simulation-Based and Competency-Based Nursing Education

Nursing education itself is a powerful intervention, and simulation-based training allows nurses and patient care technicians to practise urine collection techniques in a controlled environment, receive immediate feedback, and build confidence before performing the procedure on patients [4]. A quality improvement project in a rural Texas emergency department evaluated the impact of simulation-based education on staff knowledge, self-efficacy, and contamination rates among nurses and technicians with less than six years of clinical experience [4]. Self-efficacy scores increased significantly from pre-intervention to post-

intervention, and urine specimen contamination rates decreased from 40.7% to 13.0% [4]. Knowledge scores also improved, suggesting that simulation is effective not only for psychomotor skill acquisition but also for consolidating the cognitive elements of specimen collection, such as patient identification, labelling, and aseptic technique [4]. Competency-based education is closely related to simulation and standardisation, and hands-on training with competency sign-off ensures that staff are not merely exposed to information but are actually able to perform the procedure correctly [19]. The Plan-Do-Check-Act cycle has been applied to urine specimen collection in newborn female infants, with results showing improvements in collection success rate and cleanliness of the vaginal opening, leading to more accurate test results [19]. These findings support the broader principle that nursing education should be iterative, practical, and linked to measurable clinical outcomes, and when education is combined with audit and feedback, the gains are more likely to be sustained than when training is a one-off event [19].

Catheterised Patients and Catheter Specimen Collection

Catheterised patients represent a particularly important group for nursing intervention, because indwelling urinary catheters become colonised with microorganisms quickly after insertion and the incidence of bacteriuria is estimated at 3% to 7% per day, with nearly 100% of patients having bacteriuria after one month [7]. Distinguishing catheter-associated asymptomatic bacteriuria from genuine catheter-associated urinary tract infection is therefore essential to avoid unnecessary antibiotic treatment, but the quality of the specimen itself can confound this distinction [21]. Best practice for catheter specimen collection requires aseptic technique, and the sampling port should be disinfected with a 70% isopropyl alcohol swab before the sample is aspirated using a sterile needle and syringe [20]. If the catheter has no sampling port, the connecting tube may be disinfected and punctured with a sterile small-bore needle and syringe, but obtaining a sample from the drainage bag is not recommended [20]. Routine sampling for urine culture in asymptomatic catheterised patients is also discouraged, because it detects colonisation rather than infection and leads to unnecessary treatment [21]. Nursing interventions that standardise catheter specimen collection, empower nurses to question inappropriate culture orders, and ensure that specimens are obtained from the correct site therefore have a direct impact on both diagnostic accuracy and antimicrobial stewardship [21].

Diagnostic and Antimicrobial Stewardship: The Nurse's Role

Nursing interventions to reduce contamination are inseparable from broader efforts to improve diagnostic and antimicrobial stewardship, and urine culture stewardship is a multifaceted approach that ensures cultures are performed only when appropriate indications are present and that specimens are collected, stored, and processed in a manner that minimises contamination [22]. Nurses are uniquely positioned to contribute to this agenda because they are often the first clinicians to receive a urine culture order and the last to handle the specimen before it reaches the laboratory [22]. A review of outpatient antibiotic stewardship for urinary tract infections highlighted that nurses play a prominent role in patient education and that ensuring a proper midstream clean-catch technique is a feasible and impactful area for nurse engagement [22]. Nurse-driven checklists can prompt clinicians to reconsider urine culture orders in patients without symptoms or with non-specific findings, thereby reducing unnecessary testing for asymptomatic bacteriuria [22]. Diagnostic stewardship interventions, such as computerised clinical decision support tools that promote institutional appropriateness criteria, have been associated with an approximately 50% decrease in urine culture testing for inpatients with urinary catheters, without a significant increase in adverse outcomes [22]. Electronic stewardship interventions that prompt appropriate urine culture ordering and encourage reassessment of therapy at the time of results can further reduce inappropriate antibiotic prescribing for asymptomatic bacteriuria [23]. When nurses are empowered to "stop the line" and escalate potentially inappropriate cultures to unit managers and infection preventionists, the effect is amplified across the organisation [23]. These stewardship activities do not replace meticulous collection technique; rather, they complement it by ensuring that the right specimens are collected for the right reasons [23].

Additional Considerations for Pediatric and Catheterised Populations

Pediatric urine collection deserves particular attention because contamination risk is highly method-dependent, and urine bag collection in infants and young children is associated with contamination rates as high as 60% to 80% due to prolonged contact with perineal skin flora [24]. Nursing interventions in pediatric settings should therefore prioritise cleaner collection methods when clinically appropriate and should use structured education and competency assessment for staff who perform collection in infants and young children [24]. In catheterised adults, a multimodal and multidisciplinary catheter-associated urinary tract infection prevention initiative that included standardised urine culture protocols, education on dependent loop prevention, two-person insertion procedures, and monitoring of catheter order compliance achieved improvements in urine culture card

compliance from 15.4% to 100% and reductions in inappropriate urine cultures [25]. These findings demonstrate that nursing interventions are most effective when they are adapted to the population, the collection method, and the local system of care [25].

Multidisciplinary Quality Improvement and Audit-Feedback

Although nursing interventions are central, they are most effective when embedded within a multidisciplinary quality improvement framework [3]. A hospital that sought to minimise urine specimen contamination used a multidisciplinary team comprising a clinical nurse specialist, microbiology and laboratory personnel, and other stakeholders to review literature, collect and analyse data, provide staff education, and change urine collection kits and processing, and this approach significantly improved the quality of urine specimens in a 350-bed hospital [3]. Similarly, a multimodal and multidisciplinary catheter-associated urinary tract infection prevention initiative that included standardised urine culture protocols, education on dependent loop prevention, two-person insertion procedures, and monitoring of catheter order compliance achieved improvements in urine culture card compliance from 15.4% to 100% and reductions in inappropriate urine cultures [25]. Audit and feedback are essential components of these multidisciplinary efforts, and regular observational audits of technique, monitoring of laboratory-reported contamination rates per unit, and sharing of data with nursing and stewardship teams create a closed-loop system that links collection quality to prescribing decisions [2]. Data-driven multidimensional intervention models that combine patient education, standardisation of nursing procedures, optimisation of materials, laboratory information system-based traceability, and quality feedback systems have achieved substantial reductions in contamination [2]. In one study, the contamination rate decreased from 17.8% to 8.7%, with an absolute risk reduction of 9.1%, and sample collection compliance improved from 62.6% to 88.4% [2]. These results demonstrate that when nursing interventions are systematic, measured, and fed back to frontline staff, they produce durable improvements in specimen quality [2].

Table 1. Approximate Contamination Rates Associated with Different Urine Collection Methods

Collection method	Typical contamination rate or relative risk	Key nursing considerations
Clean-catch midstream urine in adults	Approximately 14–16% in some studies; variable depending on technique and population	Requires structured patient education, cleansing, and midstream collection; technique fidelity is critical
Urine bag collection in infants and young children	As high as 60–80% due to contact with perineal skin flora	Highest risk among non-invasive methods; should be avoided when a cleaner specimen is essential
Catheter specimen from sampling port using aseptic technique	Generally low when the port is disinfected and correct technique is used	Must never be obtained from the drainage bag; aseptic non-touch technique is required
Suprapubic aspiration	Lowest contamination rate, approximately 1%	Invasive; reserved for specific clinical indications; not a routine nursing procedure

Table 2. Summary of Nurse-Led Interventions and Reported Outcomes

Intervention component	Examples of nursing actions	Reported outcome or effect
Standardised protocols and checklists	Visual step-by-step guides, aseptic non-touch technique, competency sign-off	Reduced unwarranted variation and improved technique fidelity
Patient education with visual aids	Instructional videos, pictorial flyers, posters	Improved patient understanding and ability to perform clean catch
Simulation-based training	Hands-on practice, immediate feedback, self-efficacy building	Contamination rates decreased from 40.7% to 13.0% in one emergency department project

Catheter specimen standardisation	Sampling port disinfection, sterile aspiration, avoidance of drainage bag	Improved diagnostic accuracy and support for antimicrobial stewardship
Audit and feedback	Observational audits, unit-level contamination rate monitoring, data sharing	Sustained compliance and identification of areas needing support
Multidimensional quality improvement	Patient education, procedure standardisation, material optimisation, laboratory information system traceability, and feedback	Contamination rate decreased from 17.8% to 8.7%; compliance improved from 62.6% to 88.4%

CONCLUSION

The evidence reviewed in this essay demonstrates that nursing interventions are not merely adjunctive measures in urine specimen collection; they are decisive determinants of specimen quality and, by extension, of diagnostic accuracy, patient safety, and antimicrobial stewardship. Contamination of urine specimens is a preventable pre-analytical error with measurable clinical and economic consequences, and it arises from a combination of patient-related, technique-related, and system-related factors. The clean-catch midstream technique remains the cornerstone of voided specimen collection, but its effectiveness depends on structured patient education, anatomical understanding, and technique fidelity. Nurse-led standardisation, simulation-based training, competency assessment, catheter specimen protocols, diagnostic stewardship, and multidisciplinary audit and feedback all have demonstrated effectiveness in reducing contamination and improving compliance. The most successful interventions are those that combine multiple components—education, standardisation, equipment, feedback, and stewardship—and that are embedded within a culture of continuous quality improvement. Nursing practice at the frontline of specimen collection therefore holds enormous potential to improve diagnostic stewardship and patient outcomes, and further research should focus on sustaining these gains across diverse clinical settings and patient populations.

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