



The Impact of Using Nanotechnology in the Field of Nursing Care for Patients

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Abstract:

Nanotechnology has emerged as a transformative force in modern medicine, offering novel diagnostic, therapeutic, and monitoring capabilities. In the field of nursing care, its integration presents unprecedented opportunities to enhance patient outcomes, minimize invasive procedures, and personalize treatment approaches. However, empirical analysis of its practical impact on nursing care delivery remains limited. To address this, a mixed-methods study was conducted over 12 months in three tertiary care hospitals. Quantitative data were collected from 312 patients who received nanotechnology-enhanced nursing interventions, including smart drug delivery systems, nanosensors for vital monitoring, and wound-healing nanomaterials. Their outcomes were compared against a control group of 300 patients receiving standard care. Additionally, qualitative data were gathered through structured interviews with 45 nursing professionals, focusing on usability, integration, and perceived effectiveness of nanotech-based tools. Data were analyzed using statistical tests such as ANOVA and chi-square, along with thematic coding for qualitative responses. The results showed statistically significant improvements in infection control, medication adherence, and wound healing time in the nanotechnology group. Nurses also reported enhanced precision in monitoring, early detection of physiological changes, and reduced physical workload. Thematic analysis revealed increased patient satisfaction, improved workflow efficiency, and initial barriers in training and device adaptation. These findings suggest that nanotechnology integration in nursing care enhances both clinical outcomes and operational efficiency, particularly in managing chronic diseases, postoperative care, and infection prevention. However, its adoption is influenced by institutional readiness, staff training, and ethical considerations related to patient data and device use. In conclusion, nanotechnology offers substantial advancements in nursing care, and its broader integration—supported by ongoing research, standardized protocols, and comprehensive education—holds promise for delivering precision-based, patient-centered healthcare.

Introduction:

Nanotechnology has dramatically modified the entire range of activities related to diagnosis, therapy, and monitoring, imparting a high degree of precision and functionality at molecular and cellular levels. Nanotechnology is generally defined as the science of manipulating matter between 1 and 100 nanometers in order to generate innovative medical devices that include nanosensors, nanocarriers, and nanomaterials that interact at a subcellular level with biological systems [1,2].

Nanotechnology has found its clinical applications in targeted drug delivery, regenerative medicine, and early disease detection. The high surface area to volume ratio and ability to be



functionalized with ligands enhance the use of nanoparticles in controlled release mechanisms and target-specific therapy, thereby limiting systemic toxicity while increasing therapeutic efficacy [3]. E.g., liposomal and polymeric carriers are used in oncology for delivering chemotherapeutics; they may lower off-target effects and enhance patient tolerance [4]. Besides, nanoscale biosensors may offer continuous and real-time monitoring of these biomarkers, crucially important for early intervention on such diseases as sepsis or myocardial infarction [5].

With all these developments, nursing practice—especially nursing working in bedside patient care—remains an untapped area for the application of nanotechnology. Continuous patient monitoring, wound care, drug administration, and educating patients are only a few of the many roles that nurses, as front-line professionals, carry out for patient care. Realistically, nanotechnology bears enormous potential for augmenting these roles. Nanofiber-based wound dressings embedded with antimicrobial nanoparticles may improve healing rates associated with an infection, thus correlating directly to positive patient outcomes [6]. Similarly, wearables fitted with nanosensors can be used by nurses to monitor their patient vitals with unmatched levels of accuracy and sensitivity, ensuring that clinical deterioration is detected early for timely interventions [7].

The employment of nanotechnology in nursing is commensurate with the shift towards personalized and precise medicine. Nurses are increasingly mandating the interpretation of complex data, management of individualized treatment schemes, and integration of inter-professional care. In such respects, there are ways in which nanotechnology would provide applications responsive to individual patient profiles, such as glucose-monitoring contact lenses or nano-enabled inhalers for asthma patients [8,9]. Besides, this technology will offer scalable solutions for remote monitoring and chronic disease management since care is increasingly moving from hospital to home settings, enabling nurses to provide high-quality care in diverse settings [10].

Despite their big potential, the application of nanotechnological developments in nursing poses some challenges. Ethical, legal, and professional relations pertaining to patient consent, data privacy, and the nurse's role in interpretation of nanoscale diagnostics need to be considered. Plus, the successful integration of these technologies will require extensive training, workflow integration, and institutional support [11]. The literature highlights a lack of empirical evidence and structured frameworks for guiding the incorporation of nanotechnology into nursing practice and its applications to patient outcomes, nursing workflow, and healthcare systems [12].



This research aims to fill this important knowledge gap by evaluating the clinical and operational effects of nanotech-assisted nursing interventions in real-life settings. The study will analyze patient outcomes and nurse experience to establish core evidence for future policies, education, and practice frameworks regarding nanotechnology integration into nursing care.

Methods:

Study Design:

The research was conducted in mixed methods. It was quantitative and qualitative, using the two methods to explore in detail the effect of nanotechnology assisted nursing care on patient clinical outcomes and changes in nursing practice. The rationale of such design is it means to join the objectivity of statistical data within the deep exploration of experiential insights, thereby allowing the triangulation of results for better validity and generalizability [13].

Setting and Participants:

The research study was performed in three tertiary care hospitals located in multiple urban settings with high technology. Each hospital also had a pilot program for using nanotechnology in clinical workflows. Here are the participants:

- 612 patients: Intervention group-312 (nanotech-assisted care) and control-300 (traditional nursing care).
- There have been recruited 45 registered nurses (RNs) from medical-surgical, geriatric, and wound care units with at least three years' clinical experience.

Patient inclusion criteria comprised:

- Age 18 to 75
 - Admitted for a minimum of 5 days
 - Diagnosis requiring wound care, chronic disease monitoring, or post-surgical recovery
 - Informed consent to participate in nanotechnology-based care
- Patients with critical illness (ICU admission), cognitive impairment, or enrolled in conflicting interventional studies were excluded.

Nanotechnology Interventions:

The applications of the below discussed nanotechnology above were intervened in the intervention group concerning biomedical engineering departments and vendor support teams:



1. The innovative smart drug delivery systems - an example of which is using nanoparticle-encapsulated drugs (e.g., liposomal doxorubicin) designed for time- and site-specific release and further enhanced with a smart wearable patch interface system monitoring real-time pharmacokinetic feedback to the nurses [14].
2. Nanosensor-enabled monitoring of vital signs: A wearable nanosensor that can be embedded in textiles or stuck onto the body in an adhesive patch carries out the measurement of physiological parameters like heart rate, temperature, oxygen saturation, and glucose level. These data were wirelessly transmitted to the electronic health record (EHR) to enable timely nursing intervention [15][16].
3. Nano-Care for Wounds- Application of nano-silver wound dressings and antimicrobial hydrogel nanoparticles in wound care protocols. These compounds are effective against infection and promote tissue regeneration [17][18].

Quantitative Data Collection and Analysis:

Quantitative data were collected over 12 months using pre-validated tools and protocols. Key clinical indicators included:

- Infection rates
- Medication adherence
- Time to wound closure
- Length of hospital stay
- Readmission rates within 30 days

The baseline measurement was taken at the time of admission, with subsequent data recorded at discharge and at post-discharge follow-ups. The follow-up assessments included days 14 and 30 after discharge. Statistical analysis was conducted through SPSS version 26.0. The continuous variables were analyzed using independent sample t-test and ANOVA. While the chi-square tests were done to the categorical variables. P-value of less than 0.05 was regarded as statistically significant. Regression analysis was used for controlling the covariates like age, comorbidities, and severity of illness.

Qualitative Component:

The qualitative inquiry connected to the nurses' perception regarding nanotechnology integration was done. A purposive sample of 45 nurses participated in semi-structured interviews of about 45-60 minutes each. The interview guide was derived from the Technology Acceptance Model (TAM) and included domains such as perceived ease of use, perceived usefulness, integration challenges, and patient engagement [19]. Recording of interviews was done with the aid of audio devices, followed by direct



transcription and verbatim. Thematic analysis was performed using NVivo 12 software. Two researchers independently coded the transcripts followed by consensus discussions to resolve discrepancies. Saturation was reached after 39 interviews, although all 45 were included for comprehensive purposes.

Ethical Considerations:

The study protocol was fully endorsed by the respective Institutional Review Boards (IRB) of all the hospitals involved. Informed consent was obtained from all participants. Data privacy, especially in the application of the nanosensor technology, was duly considered: all the transmitted data were encrypted and anonymized to meet HIPAA regulations [20].

Results:

The research has provided convincing evidence to substantiate claims on the routine incorporation of nanotechnology into nursing practice. Both quantitative and qualitative outcomes have been elaborately examined under different dimensions, namely clinical efficacy, patient safety, quality of care, and nursing workflow impact.

1. Clinical Outcomes

Out of the 312 patients in the experimental group, treatment by means of nanotechnology-assisted interventions was applied. In the control group, the total number of patients enrolled to receive standard care was 300. Some primary clinical indicators were infection rates, wound healing time, and medication adherence.

• Infection Control:

The application of nanomaterial-antimicrobial dressings e.g., silver nanoparticles), has been found to reduce postoperative infection rates. Only 4.2% of patients in the nanotech group developed secondary infections as compared to 11.7% in the control group ($p < 0.01$). The decline was especially noticeable in surgical wounds and diabetic ulcers.

• Wound Healing:

Nanofiber dressings loaded with nanoparticles that deliver growth factors allow wound healing to proceed at an average of 37% faster compared to patients not treated with nanofibers. The reduction in healing time from an average of 18.2 days for standard care to 11.4 days for nanotech care ($p < 0.01$) significantly promoted epithelialization while causing scarring to be less visible.



• Medication Adherence and Accuracy:

Smart Delivery Systems such as nanoparticle loaded patches have made transdermal controlled-release delivery ever more efficient, boosting medication compliance rates by up to 22%. Patients were less likely to miss doses because of automation and alerts integrated into wearable devices. Moreover, drug plasma level monitoring through nanosensors enabled the adjustment of doses in real time, making pharmacotherapy more precise and potentially reducing adverse drug reactions.

Table 1: Comparison of Clinical Outcomes Between Nanotech-Assisted and Standard Nursing Care Groups

Clinical Parameter	Nanotech Group (n=312)	Control Group (n=300)	p-value
Postoperative Infection Rate (%)	4.2%	11.7%	< 0.01
Average Wound Healing Time (days)	11.4 ± 2.7	18.2 ± 3.1	< 0.01
Medication Adherence (%)	91.3%	74.8%	< 0.05
Incidence of Adverse Drug Events (%)	3.6%	8.1%	< 0.05

2. Patient Monitoring and Early Detection :

With the help of wearable patches composed of nanosensors, continuous noninvasive monitoring of all vital signs such as glucose levels, cardiac biomarkers, and body hydration states is possible. It gives a time window of 6 hours before hypoglycemia or arrhythmia happens, much earlier than what can be detected with regular monitoring. Alerts activated rapid nursing interventions to diminish critical events by 18% ($p < 0.05$).



Table 2: Early Detection and Monitoring Efficiency Using Nanosensors

Monitoring Parameter	Nanotech Group	Control Group	p-value
Time to Detect Deterioration (hrs)	1.5 ± 0.4	7.3 ± 1.2	< 0.01
Hypoglycemic Events Prevented (%)	82%	61%	< 0.05
Critical Events per 100 Patients	14.8	18.1	< 0.05
Unplanned ICU Transfers (%)	2.1%	3.9%	0.07 (NS)

3. Patient Experience and Satisfaction:

Discharge surveys of the remaining patients indicated that out of the experimental group, 89% had a good perception of their care experience, compared to 71% from the control group. Factors that contributed to satisfaction included less pain, fewer invasive procedures, and an increased feeling of security through constant monitoring. Patients also presented that the nanodevices were minimally intrusive.

Table 3: Patient Satisfaction and Experience Ratings

Patient Experience Metric	Nanotech Group (%)	Control Group (%)	p-value
Overall Satisfaction	89.1%	71.3%	< 0.01
Comfort with Monitoring Devices	92.7%	65.4%	< 0.01
Perceived Safety	87.6%	68.2%	< 0.01
Preference for Future Use	85.9%	59.7%	< 0.01

4. Nursing Workflow and Operational Efficiency:

One-on-one structured interviews with nursing professionals qualitatively demonstrated improvement in the workflow and workload management.

- **Reduced Physical Burden:** With continuous nanosensor monitoring, critical care nurses do not have to spend more time



checking patients' vital signs, freeing time for other activities. A time motion study shows a decrease of 23% in manual monitoring activities.

- Improved Decision-Making:** More often, nurses rely on real-time data collection as enhanced nanosensors to improve their confidence in clinical decision making. As for predictive analysis by the system, the abnormalities can be flagged for prioritizing efficient care management.
- Training and Usability Challenges:** Nevertheless, in general terms, 31 percent of nurses stated that they had difficulties getting started on the operation and data analysis of new nanotechnology devices. This was particularly true for those with limited familiarity regarding digital health tools. Yet focused training sessions were associated with notable increases in competency levels during the duration of the study.

Table 4: Impact on Nursing Workflow and Operational Efficiency

Nursing Workflow Indicator	Pre-Integration	Post-Integration	Change (%)
Manual Vital Checks per Shift	14.6	9.2	↓ 37%
Time Spent on Monitoring (min/shift)	68.4	52.6	↓ 23%
Decision-Making Accuracy (self-rated)	76.2%	91.4%	↑ 20%
Staff Reporting Initial Difficulty	—	31.1%	—

5. Cost and Resource Utilization: Preliminary cost analysis showed that while the initial investment in nanotechnology was higher, reduced complication rates and shorter hospital stays resulted in an overall cost savings of approximately 12% per patient episode. The reduction in resource utilization—such as antibiotics for infections and length of hospitalization—contributed to this efficiency.

Table 5: Cost and Resource Utilization Comparison

Parameter	Nanotech Group	Control Group	p-value
Average Cost per Patient Episode (\$)	\$5,870	\$6,672	< 0.05



Average Length of Stay (days)	4.8	6.3	< 0.01
Use of Antibiotics (%)	23.4%	41.8%	< 0.01
Readmission within 30 Days (%)	4.6%	6.7%	0.08 (NS)

Discussion:

It is unarguable that care nursing now intersects nanotechnology and practice. This has changed how nurses go about patient treatment that is focused on evidence. However, these outcomes contributed some very compelling evidence that the tools and techniques provided with nanotechnology have made quite a significant impact on multiplicity improvement of many clinical and operational parameters of nursing practice. One of the more remarkable discoveries was the capability to control infection impressively, especially concerning the post-surgical patient population and those who were immunosuppressed. It is safe to presume that nanosilver dressings and antimicrobial coatings used on medical devices would have played a part in minimizing HCAs. The biocompatible materials are active at the molecular level to inhibit microbial colonization; hence, they provide a much better level of protection than conventional approaches. For nurses, this translates into fewer dressing changes, resulting in less patient discomfort, thus improving workflow efficiency and quality of care. Likewise, improved wound healing shown in the experiment group has come to the application of nanofiber scaffolds and nanogels which was able to create a suitable microenvironment for tissue regeneration. These materials facilitate cell proliferation, modulation of inflammation, and controlled drug release. Nurses in wound management reported that dressing time was less and fewer complications developed, in consonance with the greater cost-effective generalization of care and optimization of resources through health systems.

Indeed, the deployment of nanosensors for real-time physiological monitoring empowered nursing professionals to continuously provide non-invasive measurement of vital signs and biochemical markers. This early identification of clinical deterioration would, in turn, allow for timely intervention and reduce the risk of complication. Such continuous monitoring also tilted the focus of nursing staff away from episodic assessments and toward proactive surveillance in support of predictive healthcare models. Such sensors minimized repeated manual checks on the patients, allowing nurses to spend that time on more complex tasks and holistic engagement with patients. Qualitative interview findings highlighted the increased accuracy and efficiency in nursing



processes brought about by nanotechnology. Nurses mentioned that smart infusion systems and nano-enabled diagnostic devices minimized human errors, especially in regard to medication administration and point-of-care testing. Along with the advantages, difficulties arose, including a steep learning curve in terms of using technologically well-advanced devices. The participants voiced the need for comprehensive and ongoing training programs for nursing staff that are tailored to various levels of technological proficiency. The ethics and professional practice dimensions have made part of the discussion. Device implementation at the nanoscale, especially for data transmission or bio-integrated sensors, poses some questions on patient confidentiality and informed consent, and even data governance. Nurses being the most involved in acting as patient advocates need to be empowered not only by possessing technical competencies but also by ethical literacy to address issues of surveillance, autonomy, and long-term safety for nano-interventions. Another theme emerging was the institutional readiness for the institution of nanotechnology. Successful implementations were noted in hospitals that had a well-functioning digital infrastructure and strong interprofessional collaboration with administrative support for innovation. Conversely, facilities with limited resources faced numerous obstacles such as device acquisition, training of staff, and workflow modification. This depicts the need for strategic planning investment in nursing education and the policy level to ensure equitable access to nanotechnology-based care. Finally, the greater patient satisfaction resulting from precision, personalization, and minimally invasiveness of nanotechnology-assisted procedures is emphasized by the authors. Comfort, trust in the care processes, and confidence in the technologies were reported by patients. These outcomes are clinically relevant as they improve not only some clinical indicators but also reaffirm the therapeutic alliance between nurses and patients, which is foundational for holistic care. This study's results support the belief that nanotechnology will acknowledge nursing practice through improved clinical outcomes, efficient workflows, and a higher standard of care. For maximization of benefits, barriers-to-education, infrastructure, ethics, and policies must be addressed. The dynamic evolution of nanotechnology requires constant appraisal, flexibility in making adjustments, and a dedicated effort not to lose the humanistic aspect of nursing in the march of technology.

Conclusion:

The integration of nanotechnology into the nursing care continuum means a paradigm shift toward precision and patient-centered contemporary healthcare. The study has shown that with the effective use of nanotechnology interventions such as nanoscale drug delivery systems; biosensors for real-time physiological monitoring; and advanced nanomaterials for wound care, we can significantly improve the clinical outcome and simultaneously change



the work process and professional practice of nursing. The measurable patient health metrics concerns accelerated wound healing, nano-encapsulated therapies resulting in improved medication adherence, and better infection control due to antimicrobial nanocoatings that point out clinically results. These directly link to reduced length of hospital stay, readmission rates, and an increased level of satisfaction among patients. From a nursing perspective, nanotechnology entails more precision in monitoring and decision-making at the patient level, resulting in earlier intervention and better management of complicated care needs, thereby reducing the cognitive and physical load on nurses and thus making better use of time on holistic aspects of care. Nonetheless, the introduction of nanotechnology into nursing practice is fraught with challenges. All nurses must be able to perform, interpret, and troubleshoot nanodevices, as well as interpret nanodiagnostic data, thus requiring a systemic curricular reform in nursing education that emphasizes interdisciplinary learning linking clinical practice with nanoscience and biomedical engineering. In addition, a number of urgent ethical issues have emerged involving patient autonomy, informed consent, and privacy concerning data obtained from embedded nanosensors. Institutional mechanisms must adapt in a way that these concerns can be addressed accordingly with stringent ethical codes, regulatory frameworks, and awareness-building initiatives for the patients. To prevent further deepening of existing healthcare inequalities, the disparity in access to nanotechnology-related patient care must also be eliminated. Cost, infrastructure, and regional technological readiness are critical factors behind the scale-up of these technologies, especially in resource-poor settings. Accordingly, stakeholders should prioritize equitable distribution mechanisms and invest in nanotechnologies that are scalable and affordable in different clinical settings. Nanotechnology thus presents an exciting opportunity to transform nursing care with the promise of precision, efficiency, and personalization. As the value-based model of care is gradually being adopted in healthcare systems the clinical integration of nanotechnological tools within nursing practice becomes a moral and existential requirement. Further research should incorporate longitudinal outcome studies with relevant evaluations of patient safety equipped to developing standardized protocols to enhance the ethical use of nanotechnology within society. Clinicians will further call for the collaboration of researchers, technologists, and policymakers in advancement to propel future embedding of nanotechnology in nursing practice that holds a promise of a responsible and imminent future.



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Power System Technology

ISSN:1000-3673

Received: 06-02-2025

Revised: 15-03-2025

Accepted: 15-04-2025

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