

Integrated Care to Reduce Contrast Agent Extravasation in CT Enhancement Examinations

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Abstract: To explore the effectiveness of integrated care in reducing contrast agent extravasation during CT enhancement examinations. A total of 7,247 patients undergoing CT enhancement examinations in our department between August 2022 and May 2023 were selected. The 3,615 patients treated between August 2022 and December 2022 served as the control group, while the 3,152 patients treated from January 2022 to May 2022 were the research group. The research group received integrated care, while the control group received conventional care. The incidence and severity of iodine contrast extravasation and patient satisfaction with nursing care in the two groups were compared. The incidence of iodine contrast extravasation in the research group (0.27%) was lower than in the control group (0.94%), and the nursing satisfaction rate in the research group (99%) was higher than in the control group (90%). The differences were statistically significant ($P < 0.05$). The use of integrated care in CT enhancement examinations can effectively reduce the incidence of iodine contrast extravasation and improve patient satisfaction with nursing care.

Keywords: CT; Enhancement Examination; Contrast Agent; Extravasation; Satisfaction

1. Introduction

In recent years, the application of CT equipment and examination techniques has become increasingly mature, with a significant improvement in the resolution of CT devices [1]. CT enhancement examinations, as a commonly used diagnostic and therapeutic technique, can differentiate tissue densities based on the difference in iodine concentration

between normal and abnormal tissue circulation [2]. CT enhancement examinations can accurately and clearly locate abnormal tissues and their CT value changes, providing reliable lesion information, which is of great reference value for clinical diagnosis and subsequent treatment [3]. CT enhancement examinations require the rapid injection of iodine contrast agents into patients' veins using high-pressure injectors, providing accurate diagnostic support for lesion characterization, localization, and differential diagnosis through the imaging of iodine contrast agents [4]. Due to the high pressure during venous injection, patient vascular conditions, and nurse operations, iodine contrast extravasation can easily occur in enhanced CT examinations. Domestic and foreign literature reports that the incidence of enhancement leakage ranges from 0.21% to 2.38% [5]. After leakage, local tissue damage can occur, with mild manifestations such as local swelling, pain, numbness, etc., and severe cases can lead to skin necrosis or ulceration, vascular and nerve atrophy, and even compartment syndrome [6, 7]. This not only brings great pain to patients, increases medical expenses, and affects patient treatment, but also exacerbates doctor-patient conflicts [8]. By analyzing the causes and influencing factors of contrast agent leakage, discussing research, reviewing literature, and using root cause analysis for brainstorming, we proposed solutions, continuously improved nursing details and processes, strengthened integrated nursing and technical cooperation, reduced the incidence of CT enhancement examination contrast agent extravasation (Table 1), improved patient safety and satisfaction (Table 2), and achieved good results. The methods are reported below.

Table 1. Comparison of Contrast Leakage between the Two Groups:

Group	Number of cases	Mild Leakage	Moderate Leakage	Severe Leakage	Total
Integrated Tech-Nurse	3632	9	1	0	10
Control Group	3615	17	14	3	34

Note: Comparison between two groups, $X^2=7.884$, $P=0.005$

Table 2. Comparison of Nursing Satisfaction between the Two Groups

Group	Number of cases	Very Satisfied (Cases)	Satisfied (Cases)	Unsatisfied (Cases)	Satisfaction Rate(%)
Integrated Tech-Nurse	3632	2536(70%)	1065(29%)	31(0.9%)	99%
Control Group	3615	1734(48%)	1501(42%)	380(12%)	90%

Note: Comparison between two groups, $X^2=315.91$, $P<0.001$

2. General Information

In recent years, with the combination of 3D technology and CT imaging, CT enhancement examinations have become increasingly precise. This has led to a yearly increase in enhancement examinations, with CT examination enhancement rates reaching over 40% [9]. High-pressure intravenous contrast medium leakage is the main complication of CT enhancement examinations [10]. Our department began performing CT enhancement examinations in 2002, evolving from manual syringe injections to using electronic high-pressure injectors and intravenous catheter techniques. The use of high-pressure injectors has improved the imaging results, ensuring the quality of the examination. However, due to the increased pressure and flow rate when using high-pressure injectors, the occurrence rate of contrast medium extravasation during CT enhancement examinations has increased, affecting the satisfaction of patients, ward doctors, and nurses with the radiology department. In order to alleviate patient pain, reduce the average length of hospital stays, decrease medical expenses, and prevent intensifying doctor-patient conflicts, reducing the rate of contrast medium extravasation during CT enhancement examinations has become a particularly prominent nursing issue in the radiology department.

Our department has four CT machines, of which two are mainly used for CT enhancement examinations. We are equipped with four high-pressure injectors and two

contrast medium thermostatic storage boxes. Each CT machine is staffed with one scanning technician, one post-processing technician, one circulating preparation nurse, and one injection nurse. We have a nearly 100 square meter enhancement examination waiting and observation area, along with two information display screens. We selected 7,247 patients who underwent CT enhancement examinations in our department from August 2022 to May 2023 as research subjects. Of these, 3,615 patients who visited from August 2022 to December 2022 formed the control group, while 3,152 patients who visited from January 2022 to May 2022 formed the research group. The research group received integrated nursing care, while the control group received conventional nursing care. We have identified several key factors that influence contrast medium extravasation: the physicochemical properties of the contrast medium and how temperature affects its pressure on blood vessels. If the contrast medium is preheated, its crystalline particles and viscosity decrease, reducing the pressure created by a large number of liquid particles entering the blood vessels in a short time, effectively reducing the occurrence of contrast medium leakage [11]. Especially in colder temperatures, warming the contrast medium to near body temperature can reduce its adverse stimulation of blood vessels and also reduce the occurrence of contrast medium allergic reactions [12]. The skill level of nurses and effective communication with patients are two important reasons affecting contrast medium

leakage [13-15]. Improper blood vessel selection for puncture, lack of proficiency in venous puncture techniques, and multiple puncture attempts can lead to contrast medium leaking from damaged blood vessels during CT enhancement scanning. Inadequate communication with patients, failure by the nurse to fully inform the patient of precautions before venous puncture, and movement of the patient's arm after puncture, leading to needle displacement or blood vessel rupture, can result in contrast medium leakage during high-speed injection. To ensure patient safety during examinations, not only do nurses need excellent intravenous catheter puncture skills, but they also need good communication and cooperation between the nurse and patient, and between the nurse and technician. Reasonable procedure design, effective assessment, and communication during the examination process are key to reducing contrast medium extravasation.

3. Improvement Methods

3.1 Enhance the Identification of High-risk Patients for Extravasation by Nursing Staff

Patients with a long history of radiation or chemotherapy, or with poor vascular conditions, possess thinner and more fragile veins. Consequently, they are prone to vessel rupture and medication leakage when a substantial pressure is applied during contrast administration. Factors like obesity, less visible veins, agitation, and the inability of children to cooperate can affect the success rate of venous punctures. It's essential for nursing staff to efficiently recognize such high-risk individuals. For this purpose, an "Assessment Form for CT Enhanced Examination Patients" is designed, targeting the high-risk group for contrast extravasation. This form ensures a proper assessment of the patient's physiological and pathological state, as well as their vascular structure and function. Age, physiological condition, underlying diseases, and related complications are vital contents for identifying high-risk patients. Children have smaller veins, lower cognitive levels, and less self-control, making them more susceptible to drug leakage during venous puncture. In contrast, the elderly exhibit loose skin, greater vascular mobility, reduced vascular elasticity, and imbalances in vascular structure and function, raising the

likelihood of venous leakage. Identifying such patients and highlighting them on the "CT Enhanced Examination Assessment Form" ensures effective coordination with in-room nurses and technicians. Such high-risk patients are then given special attention, with an emphasis on pre-injection testing.

3.2 Improve the Venous Cannulation Technique of Nursing Staff to Reduce the Rate of Second Punctures

If nurses aren't proficient in venous puncture, they may have to attempt multiple times, leading to a higher risk of contrast leakage from the injured vessel during CT enhanced scanning. Under the hospital's three-level quality control structure in the nursing department, there is a focus on enhancing professional learning and operational skill training. This approach helps in improving venous puncture techniques, discussing, and reviewing cases of contrast leakage, and summarizing experiences.

3.3 Strengthen Patient Health Education and Psychological Care.

Before the examination, both patients and their families receive relevant knowledge and psychological care, ensuring that conscious patients are well-informed, thereby increasing their cooperation and reducing the risk of contrast leakage.

A three-tiered education approach is applied to patients undergoing CT-enhanced examinations: registration staff provide informed consent via "CT Enhanced Examination Informed Consent Form", detailing indications, medication contraindications, special preparations, etc.; information regarding the testing procedure is displayed before injection; and injection nurses offer education on the purpose, methods, and relevant precautions of CT enhanced scanning. This ensures that the patient's anxieties are alleviated, allowing them to be proactive and cooperative during the examination, subsequently reducing the risk of contrast leakage.

3.4 Strengthen Contrast Medium Storage Management to Ensure its Temperature is between 35-37.5°C [16].

A SOP (Standard Operating Procedure) for the constant temperature box is established,

specifying the responsibilities of the circulating nurse in the scanning room to ensure the proper temperature of the contrast medium. When the iodine contrast medium reaches a temperature of 37-37.5°C, its crystalline particles and viscosity decrease, effectively reducing the pressure caused by large amounts of fluid particles entering the bloodstream in a short time and thus preventing leakage.

3.5 Enhance Integrated Assistance between Nurses and Technicians, and Improve Communication among CT scan Technicians, Nurses, and Patients.

Nurses assess the veins and provide injection rate recommendations to the technician to minimize contrast leakage. They also collaborate on the injection site positioning based on the examination area to further reduce leakage. A lack of communication is a significant cause of contrast leakage.

Establish a standard operating procedure for technicians. Strictly enforce the technical operation standards. Technicians should communicate with nurses and patients when positioning, to avoid compressing the puncture site's blood vessels or limb movement, leading to leakage. Before scanning, check if the syringe connection tube is compressed to prevent the needle from shifting or exiting the blood vessel, causing leakage during CT bed movement. Technicians should set an appropriate injection flow rate to avoid causing excessive injection flow, resulting in local leakage. During the CT scan, technicians and nurses should closely observe the patient's reactions and the high-pressure injector's pressure curve. If the patient expresses pain or the pressure curve changes, immediately stop the contrast agent injection and scanning to avoid significant contrast leakage.

3.6 Design a Hand Support Frame for Elderly or Frail Patients to Prevent Contrast Leakage during CT Enhanced Examinations.

CT machine does not have a special support to fix the arm, the old and frail patients can not adhere to a position in the scanning process, easy to cause the needle shift, fold, resulting in leakage, after the application of arm support, improve the stability of the patient's arm, reduce the risk of exosmosis.

3.7 Evaluation Indicators

3.7.1 Iodine contrast leakage

Record the occurrence rate of iodine contrast leakage in both groups and grade the leakage as follows: mild leakage (<20 mL), moderate leakage (20-50 mL), and severe leakage (>50 mL).

3.7.2 Patient Satisfaction Survey

Conduct a survey using a self-made questionnaire, mainly including service attitude, health education, nursing operation level, and basic care satisfaction. Out of 100 points, scores ≥ 95 are very satisfied, 85-94 are satisfied, and < 85 are unsatisfied. Satisfaction rate = (satisfied cases + very satisfied cases) / total cases $\times 100\%$. The retest reliability of this questionnaire is 0.903, with validity ranging from 0.591 to 0.847, indicating stable structural validity, good content validity, and excellent dimensional homogeneity.

3.8 Statistical Methods

Use SPSS 25.0 statistical software for data analysis. Display qualitative data like leakage rates and nursing satisfaction with case numbers and percentages (%), using the χ^2 test. A P-value of < 0.05 indicates statistically significant differences.

4. Results

The integrated nursing and technical approach improved the radiographic quality during contrast administration for CT enhancement.

(1) Quality control target: Reduce iodine contrast leakage to 0.2%

(2) By improving nurses' recognition of high-risk patients for leakage, prioritize and monitor these patients, pre-test injections to reduce leakage rates.

(3) Improve the venous cannulation technique of nursing staff to reduce secondary puncture rates. Design patient positioning based on the injection site to avoid catheter needle breakage causing medication leakage.

(4) Enhance patient health education and psychological care, aiming for a 100% health education rate for conscious patients before examination, increasing cooperation and reducing contrast leakage.

(5) Establish SOP for a constant temperature box to control contrast temperature, improving intravenous temperature, benefiting the reduction of contrast leakage.

(6) Strengthen the integrated collaboration between nurses and technicians, enhancing effective communication between CT technicians, nurses, and patients.

(7) For the elderly or frail patients, design a hand support frame for CT enhanced examinations to prevent contrast leakage. With the help of auxiliary supports, they can support their arms, preventing catheter needle breakage and medication leakage.

5. Conclusion

Improve the identification of high-risk patients for extravasation. Nursing staff need to have the ability to effectively identify high-risk patients; through standardized three-tier quality control, strengthen technical training, improve venous catheter puncture techniques, and reduce the rate of secondary puncture; for CT enhanced examination patients, implement three-tier education to alleviate patient anxiety and concerns, improving patient cooperation, strengthening contrast agent storage management, and ensuring the temperature of the contrast agent entering the vein. When the temperature of the iodine contrast agent reaches 37-37.5°C, the crystalline particles and viscosity of the contrast agent will decrease, thus reducing the pressure caused by a large number of liquid particles entering the blood vessels in a short time, effectively reducing the occurrence of contrast agent leakage; establishing a standard operating procedure for technicians to strengthen the integrated cooperation between nurses and technicians can significantly reduce the occurrence of moderate and severe contrast agent extravasation, improving patient satisfaction.

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