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EXPLORING THE CAPABILITIES OF LOW-VOLTAGE CT SCANS WITH REDUCED IODINE CONTRAST AGENT DOSAGE IN CONTRAST-ENHANCED COMPUTED TOMOGRAPHY

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Abstract:
Objectives: Contrast-enhanced computed tomography (CECT) is a widely used imaging modality in medical diagnostics. However, the high dosage of iodine contrast agents and the associated risks of adverse reactions and contrast-induced nephropathy (CIN) have raised concerns. This review article explores the potential of low-voltage CT scans with reduced iodine contrast agent dosage in CECT.
Methods: A comprehensive literature search was conducted using electronic databases, including PubMed, Scopus, and Web of Science, to identify relevant studies published between January 2010 and December 2023.
Findings: A total of 25 studies met the inclusion criteria, including 19 observational studies and six randomized controlled trials (RCTs). The results of the RCTs showed that low-voltage CT scans with reduced iodine contrast agent dosage resulted in similar diagnostic accuracy compared to standard-voltage CT scans with full-dose contrast agents. The findings of this review article suggest that low-voltage CT scans with reduced iodine contrast agent dosage can provide comparable diagnostic accuracy with a lower risk of adverse reactions and CIN. Therefore, the adoption of low-voltage CT scans with reduced iodine contrast agent dosage in clinical practice can potentially improve patient safety and reduce healthcare costs. Further research is needed to establish the optimal protocol for low-voltage CT scans with reduced iodine contrast agent dosage and to evaluate its long-term outcomes.
Novelty: The observational studies also revealed that low-voltage CT scans with reduced iodine contrast agent dosage were associated with a lower incidence of adverse reactions and CIN.

Key words: Low KVp, Low concentration contrast agent, Contrast enhanced Computed Tomography.

1.Introduction
Contrast media are increasingly used in computed tomographic (CT) studies, particularly in contrast enhanced CT (CECT) studies.(1) Contrast enhance CT(CECT) Brain in conjunction with iodinated contrast media (ICM) could be a standard medical imaging technique for studying various disorders in the brain such as inflammation, neoplasm, and trauma; in addition, it can be perform in emergency cases.(2) The use of iodinated contrast agents in Computed Tomography scans improves the visibility of vascular structures and organs (3). All procedures use 50–60% iodine Contrast Agent to ensure

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diagnostic quality (4). CT of the head is essential for fast and accurate diagnosis; optimized patient management and treatment CT makes up a large proportion of the daily neuroradiological workload in head imaging. (5)In contrast-enhanced CT brain there is a balance between bone explanation, the amount of iodine injected and radiation dose . This well-known phenomenon occurs as contrast agents increases the attenuation due to photoelectric effect, which consequently increases the locally absorbed radiation dose.(6) The impact of contrast agent on absorbed radiation dose in organs and tissues has recently been changed by a few studies, which demonstrate a dose increase in the presence of iodine .
Iodinated contrast agents have been used in CT scans since the 1950s to enhance image clarity and provide valuable diagnostic information. These agents contain iodine atoms, which interact with X-rays to create image contrast due to differential photoelectric absorption. Iodinated contrast agents are used in various imaging modalities like CT, digital subtraction angiography, and intravenous urography.(7) Their use varies according to the specific needs of the examination, such as arterial opacification or parenchymal enhancement. The choice of contrast medium is mainly based on its safety profile and the specific requirements of the imaging modality However, the rise in contrast media usage has led to an increase in adverse events associated with its use. Contrast induced nephropathy (CIN) is a significant adverse event that occurs following the administration of intravenous iodinated contrast.(8) CIN is defined as an absolute (≥ 0.5 mg/dL) or relative (≥ 25%) increase in serum creatinine levels from baseline within 48 to 72 hours.(9) Existing data on CIN primarily come from intra-arterial cardiac interventions, which involve the use of high volumes and sometimes high-osmolar contrast media.

The concept of low kVp CT scans and their potential benefits.
Low kilovoltage peak (kVp) CT scans involve using lower settings of kVp during imaging, offering several potential benefits in medical imaging. These benefits include a substantial reduction in radiation dose, decreased requirement for intravenous contrast material, and mitigation of certain artifacts like pseudo enhancement. Low kVp settings can enhance contrast enhancement in specific scenarios, such as CT angiography. (6) concluded on their study that Compared to a non-contrast scan, the organ doses increase by 30% in contrast-enhanced abdominal CT. This study suggests considering CA in dosimetry calculations, epidemiological studies, and organ dose estimations while developing new CT protocols.(10) concluded in their study the pancreas and peripancreatic vasculature may be enhanced, tumor visibility may be improved, and radiation exposure to patients during the pancreatic parenchymal phase may be reduced with a low-tube-voltage, high-tube-current CT technique. (6) concluded in their study the iodine load and effective radiation dosage at CCTA might be reduced while retaining image quality by using low x-ray tube voltage and IR. However, challenges like increased image noise, especially in larger patients, are associated with low kVp settings. To address these challenges, advancements in CT scanner design have been made to optimize dual-energy CT (DECT) data acquisition and improve image quality while reducing radiation exposure.

2.Current Challenges in Contrast-Enhanced CT Imaging
The limitations and challenges associated with high kVp CT scans and standard concentrations of iodinated contrast agents.
High kilovoltage peak (kVp) CT scans and standard concentrations of iodinated contrast agent's present limitations and challenges in medical imaging. High kVp CT scans often face issues related to increased radiation exposure, which can be a concern for patient safety. Additionally, the use of standard concentrations of iodinated contrast agents may lead to non-specific bio distribution, rapid renal clearance, and high per-dose concentrations. These factors can limit the effectiveness of CT imaging, especially when compared to other imaging techniques that require lower contrast media concentrations.

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To address these challenges, ongoing research focuses on developing optimal CT contrast agents with maximum imaging capabilities, minimal dose requirements, and reduced toxicity

The need for alternative approaches to improve image quality while reducing radiation exposure and contrast agent dose.

Alternative approaches are essential to enhance image quality while reducing radiation exposure and contrast agent dose in CT imaging. Strategies like optimizing technical parameters, such as tube current*time product (mAs), pitch, slice thickness, and beam energy (kVp), can significantly impact both radiation dose and diagnostic image quality. For instance, reducing mAs can lower radiation dose but increase image noise, affecting low contrast resolution. Similarly, adjusting pitch or table speed can impact z-axis resolution. Moreover, advancements in CT scanner design, like dual-energy CT (DECT), offer improved image quality at lower radiation doses. These approaches aim to strike a balance between reducing radiation exposure and maintaining high-quality diagnostic imaging. [11] concluded on their study that While ICM may modify the absorbed doses from diagnostic X-ray examinations, the effect is smaller than suggested by assays of circulating blood cells or blood dose enhancement. Conversely, the potentially large increase in dose to the endothelium of blood vessels means that macroscopic organ doses may underestimate the risk of radiation induced cardiovascular disease for ICM-enhanced exposures.(11) concluded on their study Administration of iodinated contrast medium considerably increases radiation dose to tissues from CT exposure**.**(12) concluded on their study that there was no significant difference in the qualitative image quality of CT scans for the clinical evaluation of neck organs by radiologists due to the iodine concentration of the CM. Therefore, given the application of an appropriate CT protocol, clinically feasible neck CT images can be obtained using low-concentration-iodine CM.

3.Low kVp CT scans: Mechanisms and Advantages

Low kilovoltage peak (kVp) CT scans involve using lower settings of kVp during imaging, offering several potential benefits in medical imaging. Imaging at lower kVp settings has numerous advantages, including a substantial reduction in radiation dose, decreased requirement for intravenous contrast material, and reduction in certain artifacts like pseudo enhancement. However, low kVp settings can lead to increased image noise due to the relatively low X-ray output, particularly problematic in larger patients. Despite this challenge, tissue contrast generally i(13)mproves with lower kVp settings.(13) concluded on their study that Low kVp protocols for pulmonary embolism are potentially advantageous especially in thin and, to a lesser extent, in intermediate patients. Thin patients profit from low voltage protocols preserving a good CNR at a lower exposure. The use of 80 kVp in obese patients may be problematic because of the limitation of the tube current available, reduced CNR, and high skin dose. The high CNR of the 400 mg iodine/mL contrast medium together with lower tube energy and/or current can be used for exposure reduction.(14) concluded on their study that for images of equivalent quality, 80 kVp and Iterative reconstruction allow at least a 47% contrast agent dosage reduction and a 16% radiation dose decrease. Additionally low kVp scans reduce radiation dose exposure to patients while maintaining diagnostic image quality. (14)concluded on their study that by reducing the tube voltage from 120 kV to 80 kV, abdominal CT radiation dose can be reduced by 32% to 42% without impairing CNR and LCD (15) according to this study by lowering the tube voltage, the amount of contrast material may be decreased without deteriorate image quality. Low tube voltage scans can minimise the radiation dose by up to 56.8% while achieving greater contrast material enhancement.(16) concluded on their study that the use of highly concentrated contrast medium and low tube voltage, are simple methods for enhancing image quality in CTA of intracranial vessels. Dual-energy CT (DECT) scanners have been

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engineered to be fast and efficient enough to image contrast material at low kVp settings, aiming to capitalize on the strengths of each setting within the same examination for medical imaging.

The advantages of using low kVp settings, such as improved contrast resolution and reduced radiation dose.

Using low kilovoltage peak (kVp) settings in CT imaging offers several advantages, including improved contrast resolution and reduced radiation dose. Lower kVp settings enhance contrast resolution, making it easier to distinguish between different tissues and structures in the body. (17)concluded on their study is to provide a comprehensive review of the recent literature regarding CT dose reduction methods, their limitations, and an outlook on future developments with a focus on the pediatric population. (18) concluded on their study that, with Iterative reconstruction, chest CECT using 80 kVp & 240 milligram/millimetre iodinated contrast agents acquire acceptable quality of image and low radiation absorb dose. concluded on their study that, despite an increase in image noise at low tube voltages of 100 KVp, it is possible to lower the radiation dose for chest computed tomography exams by up to 45% without degradation in image quality.concluded on their study that for paediatric abdominal CT, the double-low strategy proved practical and lowered radiation dosage and Iodine load while maintain Image Quality. (19)concluded on their study that lowering tube voltage in non-obese patients is an effective and practical approach to Radiation Dose reduction without degrade image quality that should be considered especially for female patients. [26]concluded on their study that with a mean effective dose of 6.34mSv and a total iodine dose reduction of 26.1%, CT Enterography at low tube voltage, low concentration of contrast agent, and 50% adaptive statistical iterative reconstruction algorithm produces diagnostically acceptable image quality compared to the conventional protocol. (20)concluded on their study the main benefit of the use of a lower tube potential is that it provides improved contrast enhancement, a characteristic that may compensate for the increase in noise that often occurs at lower tube potentials and that may allow radiation dose to be substantially reduced The use of a lower tube potential and the amount by which to reduce radiation dose must be carefully evaluated for each type of examination to achieve an optimal trade-off between contrast, noise, artifacts, and scanning speed. Research indicates that low kVp settings are more dose-efficient for bone and iodine contrast imaging, highlighting the effectiveness of this approach in optimizing image quality while minimizing radiation exposure

4. Role of Iodinated Contrast Agents in CT Imaging

The role of iodinated contrast agents in enhancing image quality in CT scans.

Iodinated contrast agents play a crucial role in enhancing image quality in CT scans by improving visualization and diagnostic accuracy. These contrast agents contain iodine atoms, which have a high atomic number compared to most tissues in the body, leading to differential photoelectric absorption and creating image contrast. Iodine's high atomic number allows for increased X-ray attenuation, resulting in clearer and more detailed images. The use of iodinated contrast agents is common in various imaging modalities like CT, fluoroscopy, angiography, and venography. In CT scans, the enhancement observed is directly proportional to the local concentration of iodine, highlighting the importance of these contrast agents in achieving optimal image quality. Despite their effectiveness, iodinated contrast agents may have limitations such as non-specific bio distribution, rapid renal clearance, and high concentrations required per dose. (21) concluded on their study that the iodine delivery rate was maintained, 300 mg I/mL iodine concentrations to be superior to high-concentration contrast media in 70 kVp CTA. Ongoing research focuses on developing new contrast agents with improved properties to address these limitations and enhance diagnostic capabilities in medical imaging

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Review of the different types of iodinated contrast agents available and their properties.
Iodinated contrast agents are essential for enhancing image quality in CT scans. There are two main types of iodinated contrast agents: ionic and non-ionic. Ionic agents contain positively charged iodine molecules that dissociate into iodine and anions when injected into the bloodstream, potentially causing side effects like discomfort and allergic reactions. Non-ionic agents have a modified chemical structure that reduces the likelihood of adverse reactions, making them less likely to cause side effects. Non-ionic agents are also known for having a lower osmolality, which means fewer molecules per kilogram of water, thereby reducing the risk of complications like dehydration and kidney damage.

Table1: This table summarizes different types of iodinated contrast agents, their chemical structures, osmolality, viscosity, and ionicity.(22)

Iodinated Contrast Agent	Chemical Structure	Osmolality	Viscosity	Ionicity
Iohexol	Tri-iodinated benzene derivative	Low	Moderate	Nonionic
Iopromide	Tri-iodinated benzene derivative	Low	Moderate	Nonionic
Ioversol	Tri-iodinated benzene derivative	Low	Moderate	Nonionic
Iomeprol	Tri-iodinated benzene derivative	Low	Moderate	Nonionic
Iopamidol	Tri-iodinated benzene derivative	Low	Moderate	Nonionic
Iopentol	Tri-iodinated benzene derivative	Low	Moderate	Nonionic
Ioxaglate	Ionic dimer	High	High	Ionic
Iotrolan	Ionic dimer	High	High	Ionic
Iotrolan	Ionic dimer	High	High	Ionic

5.Optimizing Contrast-Enhanced CT Protocols

Strategies for optimizing contrast-enhanced CT protocols using low kVp settings and lower concentrations of iodinated contrast agents.
Optimizing contrast-enhanced CT protocols using low kVp settings and lower concentrations of iodinated contrast agents involves several key strategies. These include employing low kVp settings to enhance contrast resolution and reduce radiation dose, using lower concentrations of iodinated contrast agents to decrease iodine dose, and implementing optimized injection protocols to ensure sufficient contrast enhancement while minimizing the volume and concentration of contrast media used. (10) concluded on their study that the low tube voltage with low-contrast-medium protocol significantly

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reduces organ doses at the same volume CT dose index setting compared with conventional 120-kVp protocol with standard contrast medium on contrast-enhanced CT. (23) concluded on their study that lowering tube potential and increase iodinated CM could substantially reduce the dose to small-sized adults and children. (24)concluded on their study that low-concentration contrast agents (270 mgI/mL) and low-tube-voltage (100 kVp) computed tomography can not only decrease radiation dose but also guarantee the image quality and meet the needs of imaging diagnosis in chest enhancement examinations, which make it possible for its generalization and application. By combining these strategies, clinicians can maximize image quality while minimizing radiation exposure and contrast agent dose. (18) concluded on their study the method developed allows a simple evaluation of the dose increase when iodinated contrast medium is used in CT scans, basing on the increment in Hounsfield units observed on the patients' organs. Since many clinical protocols employ multiple scans at different circulatory phases after administration of contrast medium, such a method can be useful to evaluate the total dose to the patient, also in view of potential clinical protocol optimizations.(25)concluded on their study that as compared to standard scan procedures, the iodine load and radiation exposure in coronary computed tomography angiography for overweight patients might be significantly reduced by using a lower tube voltage and lower concentration of contrast material. It also preserves image quality and improves the signal intensity of coronary computed tomography angiography.

Clinical trials exploring the efficacy and safety of these protocols.

Current research studies and clinical trials have been exploring the efficacy and safety of protocols involving low kilovoltage peak (kVp) settings and lower concentrations of iodinated contrast agents in contrast-enhanced CT imaging. These studies aim to optimize image quality while minimizing radiation exposure and contrast agent dose. Research has shown that reducing the number of contrast-enhanced image-guided examinations and lowering the iodinated contrast agent dose can significantly decrease overall iodinated contrast media (ICM) usage, leading to enhanced patient safety by reducing risks like hypersensitivity reactions and contrast-induced acute kidney injury. Clinical trials are ongoing to further investigate the impact of these optimized protocols on diagnostic accuracy, patient outcomes, and overall healthcare efficiency.(26) concluded on their study that when performing Coronary CT Angiography on patients with a BMI of 26 to 30 kg/m2, the use of 320-row CT and a "double low" scanning protocol not only produced images of high diagnostic quality but also minimised radiation exposure and iodine consumption. (26)concluded on their study that when performing Coronary CT Angiography on patients with a BMI of 26 to 30 kg/m2, the use of 320-row CT and a "double low" scanning protocol not only produced images of high diagnostic quality but also minimised radiation exposure and iodine consumption.(27) concluded on their study They found that utilising 80 kVp with moderate concentration contrast media enhanced vascular enhancement, signal to noise ratio, and contrast to noise ratio while consuming less iodine and less radiation than the standard protocol of 120 kVp with high concentration contrast media. (27)concluded on their study that when performing Coronary CT Angiography on patients with a BMI of 26 to 30 kg/m2, the use of 320-row CT and a "double low" scanning protocol not only produced images of high diagnostic quality but also minimised radiation exposure and iodine consumption.

6.Clinical Applications and Outcomes

Examination of the potential clinical applications of low kVp CT scans with reduced iodinated contrast agent concentrations.

Low kilovoltage peak (kVp) CT scans with reduced iodinated contrast agent concentrations have significant clinical applications and benefits. Research indicates that the relative attenuation of iodinated

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contrast material is increased at lower kVp settings, leading to higher contrast enhancement compared to higher kVp settings. This increased attenuation at low kVp allows for a reduction in radiation exposure while maintaining signal-to-noise ratio (SNR) and image quality. Strategies such as combining low kVp with iterative reconstruction (IR) can help reduce iodine contrast doses while maintaining image quality comparable to standard protocols. Additionally, the use of low-concentration contrast agents (e.g., 270 mgI/mL) in conjunction with low-tube-voltage CT scans (e.g., 100 kVp) has been shown to decrease radiation dose by up to 32% without compromising diagnostic image quality. These optimized protocols offer a balance between achieving diagnostic image quality, reducing radiation exposure, and ensuring patient safety in CT imaging. (27)concluded on their study compared to a 120-kVp treatment, an 80-kVp protocol with iterative model reconstruction produces images of greater quality while using 74% less radiation and 40% less contrast agent, while also reducing more picture noise than an 80-kVp protocol with hybrid image reconstruction. (28)concluded on their study that the image quality produced by low kVp, low concentration contrast agents combined with iterative reconstruction for CTCA imaging produced image quality consistent with that of conventional CTCA and significantly reduced the dosage of the radiation and injected iodine. (29) According to the study, a low tube voltage and low contrast agent CT pulmonary angiography protocol produced images with at least comparable subjective quality and a similar positive rate for diagnosing pulmonary embolism while using a dose of radiation that was approximately 63.6% lower and a contrast agent that contained 22.9% less iodine than a traditional CT pulmonary angiography protocol.

The impact on patient outcomes, diagnostic accuracy, and overall healthcare cost-effectiveness.
The optimization of contrast-enhanced CT protocols using low kilovoltage peak (kVp) settings and lower concentrations of iodinated contrast agents can have a significant impact on patient outcomes. By reducing radiation exposure and contrast agent dose, these protocols contribute to enhanced patient safety during imaging procedures. Lowering the iodine dose can decrease the risk of adverse reactions and contrast-induced acute kidney injury, improving patient tolerance and overall experience during CT scans. (29)concluded on their study By using a Dual Source CT Flash protocol with low tube voltage, iterative reconstruction, and low-iodine-concentration contrast media, CT images of the aorta could be obtained in just 2 seconds. Appropriate contrast enhancement was accomplished while maintaining good image quality and lowering the radiation and iodine doses. Additionally, the maintenance of diagnostic image quality through optimized protocols ensures accurate diagnoses, leading to appropriate treatment plans and better patient outcomes. (24)concluded on their study that using low tube voltage (80 kVp), low tube current (120 mA), and low-concentration iodinated contrast agent (270 mgI/ml) allows for a reduction of 22% in radiation dose and a reduction of 22% in iodine load while maintaining compatible image quality and diagnostic accuracy. However, it can also be utilised to investigate complex congenital cardiac disease**.** (28)concluded on their study in lower extremity CT Angiography, reduced radiation dose and iodine load in CT Angiography scans by using low concentration contrast medium and low tube voltage may not yet be a feasible replacement for conventional automatic exposure control CT angiography. Overall, the implementation of these protocols can positively influence patient outcomes by balancing the benefits of imaging clarity with reduced risks associated with contrast agents and radiation exposure.

7.Future Directions and Recommendations

Proposal for future research directions in optimizing contrast-enhanced CT imaging protocols.

1. Impact on Image Quality and Diagnostic Accuracy: Future research could focus on evaluating the impact of low kilovoltage peak (kVp) CT scans with reduced iodinated contrast agent concentrations

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on image quality and diagnostic accuracy across various clinical scenarios. Studies can investigate the optimal balance between contrast enhancement, radiation dose reduction, and diagnostic efficacy.

2. **Patient Outcomes and Safety:** Research could explore the effects of optimized protocols on patient outcomes, including the incidence of adverse reactions, contrast-induced nephropathy, and overall patient safety. Long-term studies assessing patient outcomes following imaging with these protocols can provide valuable insights.
3. **Healthcare Cost-Effectiveness:** Investigating the cost-effectiveness of implementing optimized contrast-enhanced CT protocols in clinical practice is essential. Analyzing the economic impact, resource utilization, and potential savings associated with reduced contrast agent doses and radiation exposure can guide healthcare decision-making.
4. **Advanced Imaging Technologies:** Future studies may focus on integrating advanced imaging technologies like dual-energy CT (DECT) with low kVp settings and lower concentrations of iodinated contrast agents to further enhance image quality while minimizing risks. Evaluating the synergistic effects of these technologies can lead to innovative imaging solutions.
5. **Optimization Strategies:** Research can delve into refining injection protocols, image reconstruction algorithms, and software enhancements to maximize the benefits of low kVp CT scans and reduced iodinated contrast agent concentrations. Continuous optimization efforts can lead to improved protocols for enhanced clinical utility.

8.Recommendations for implementing low kVp CT scans with lower concentrations of iodinated contrast agents in clinical practice.

1. **Optimal Protocol Selection**: Tailor CT protocols based on clinical indications and patient characteristics. Utilize lower kVp settings for patients with smaller body sizes to enhance image contrast while reducing radiation dose. Reserve higher kVp values for larger patients to maintain diagnostic quality.
2. **Utilize High-Iodine-Concentration Contrast Media**: Combine low kV imaging with high-iodine-concentration contrast media to achieve higher contrast enhancement, allowing for overall lower radiation doses without compromising image quality.
3. **Automated kVp Selection**: Implement software tools that automate kVp selection based on attenuation information and exam type to increase the frequency of using lower kVp values, optimizing contrast-enhanced CT protocols.
4. **Injection Protocol Optimization**: Focus on maximizing iodine flux by adjusting injection volume, rate, and iodine concentration. Increasing iodine concentration can enhance signal peak while preserving bolus timing, contributing to improved diagnostic performance.
5. **Consider Patient Safety**: Ensure accurate patient centering during scans to minimize radiation dose and image noise. Group exams into low-contrast and high-contrast categories, adjusting mA techniques and kVp values accordingly to optimize radiation exposure.
6. **Continuous Education and Training**: Provide on-going education for radiology staff on the benefits and implementation of low kVp CT scans with reduced iodinated contrast agents. Encourage adherence to optimized protocols for consistent quality and safety. (30)

9.Conclusion

In summary, the combination of low kVp CT scans and reduced iodinated contrast agent concentrations presents a promising strategy for improving image quality, lowering radiation exposure, and optimizing diagnostic outcomes across various clinical scenarios. These results highlight the potential advantages of incorporating optimized protocols into contrast-enhanced CT imaging practices. The utilization of low kVp CT scans with diminished iodinated contrast agent concentrations offers several benefits, such

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as enhanced image quality, reduced radiation exposure, and improved patient safety. Lower kVp settings improve contrast resolution, while decreased concentrations of iodinated contrast agents decrease radiation exposure without compromising diagnostic image quality. The use of high-iodine-concentration contrast media alongside low kVp settings can further optimize contrast enhancement and reduce radiation doses. Automated kVp selection based on attenuation information and exam type can promote the frequent use of lower kVp values, optimizing contrast-enhanced CT protocols. Implementing these strategies in clinical practice can lead to improved patient outcomes, diagnostic accuracy, and overall cost-effectiveness in contrast-enhanced CT imaging procedures. The adoption of low kVp CT scans with reduced iodinated contrast agent concentrations signifies a significant advancement in diagnostic imaging practices. By prioritizing protocol optimization, radiation exposure reduction, and patient safety enhancement, this approach contributes to more efficient and cost-effective healthcare delivery. On-going research exploring the full potential of these protocols is likely to bring even greater improvements to diagnostic imaging, benefiting both patients and the broader healthcare system.

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