



Contrast-enhanced Computed Tomography Examinations: Discussion of Hydration Protocols for Patients with Altered Creatinine Levels

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ABSTRACT: Computed Tomography (CT) is an imaging diagnostic method that enables the visualization of internal structures in the human body, allowing for the detection of various pathologies that may affect individuals. This examination can be performed with or without contrast, which can be administered orally or intravenously. Patients with altered creatinine due to renal dysfunction may encounter difficulties in eliminating this intravenous contrast through the renal route, requiring a hydration protocol to facilitate the safe and effective completion of the examination. Considering the significance of CT in disease diagnosis, this study aims to analyze hydration protocols used in patients with altered creatinine during the performance of intravenous contrast-enhanced computed tomography. This study is an integrative literature review, where searches were conducted in databases such as PubMed/MEDLINE, BVS (Virtual Health Library), and ScienceDirect, in order to identify and list articles and research studies discussing the aforementioned subject, published between the years 2013 and 2017. The study revealed that both oral and intravenous hydration demonstrate similar efficacy in preventing contrast-induced nephropathy in patients with renal dysfunction, as detected through alterations in serum creatinine. Based on the findings, it is concluded that there is a need to continually advance research efforts to enable a growing number of patients with renal dysfunction to undergo intravenous contrast-enhanced computed tomography safely and effectively, thus enabling early diagnosis of diseases, as well as monitoring pre-existing conditions.

KEYWORDS: Computed Tomography (CT), Creatinine Alteration, Hydration Protocol, Intravenous Contrast, Renal Dysfunction.

INTRODUCTION

Computed Tomography (CT) is an imaging diagnostic method that enables the visualization of internal structures in the human body, allowing for the detection of various pathologies that may affect individuals, including cancer, brain tumors, pulmonary embolism, aneurysm, vascular disorders, and pleural diseases (MOURÃO, 2015).

The CT procedure can be performed with or without contrast, which can be administered orally or intravenously. Contrast facilitates the acquisition of more detailed images, enhancing the visualization of blood vessels, as well as proving beneficial for physiological and functional studies (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

After the administration of intravenous contrast, it is rapidly diluted in the blood plasma but is not stored in tissues. Due to its low protein binding and non-biodegradability, the contrast is eliminated from the body intact and exclusively through the renal pathway. Any alteration in organ functionality hinders its excretion (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

Therefore, intravenous contrast-enhanced CT examinations must be made available in a safe and effective manner, particularly for individuals who may exhibit indications of renal function alterations (DINIZ; COSTA; DA SILVA, 2016). It is worth noting that alterations in renal activity have numerous consequences on the physical, psychological, and social aspects of an individual (SOARES et al., 2022).

According to the Brazilian Society of Nephrology (2022), one in every 10 people worldwide has chronic kidney disease. Additionally, it is estimated that 10 million Brazilians suffer from some form of renal dysfunction, a number that is steadily increasing. These data highlights a rise in the prevalence of these diseases, causing concern among public health authorities.

Renal alterations can be detected early through the presence of high concentrations of serum creatinine, as its excretion is primarily carried out by the kidneys. The measurement of this substance, a residual product of creatine and phosphocreatine metabolism, is the most commonly used method for detecting renal activity (MALTA et al., 2020).



In order to perform intravenous contrast-enhanced CT in patients with renal function alterations, the development of hydration protocols (oral and intravenous) was necessary to mitigate the risks of potential adverse effects (INSTITUTO DE SAÚDE E GESTÃO HOSPITALAR, 2014).

In light of this, the present study addresses the following question: In what manner do hydration protocols for patients with altered creatinine effectively mitigate renal complications following an intravenous contrast-enhanced computed tomography?

In alignment with the presented data, this study is warranted to analyze and discuss the protocols currently employed for the prevention of such complications, ensuring both efficacy and safety for individuals presenting any form of renal dysfunction.

Thus, the general objective of this work is to analyze hydration protocols used in patients with altered creatinine during intravenous contrast-enhanced computed tomography, with specific objectives including highlighting the importance of intravenous contrast in computed tomography, identifying adverse effects caused by intravenous contrast, and describing through literature the types of hydration and the effectiveness of each protocol.

I. Computed Tomography

The evolution of computed tomography (CT) has seen ongoing development and refinement throughout multiple generations. It is noteworthy, however, to highlight that in 1979, electronic engineer Godfrey Newbold Hounsfield and physicist Allan McLeod Cormack were awarded the Nobel Prize in Medicine for their groundbreaking invention of computed tomography (CARVALHO, 2007).

The CT is a widely used imaging diagnostic method that aims to visualize internal parts of the human body, aiding in disease diagnosis through the study of tissue alterations (MOURÃO, 2015).

The first CT scanner was introduced in Brazil in 1977 when equipment was made available at the Hospital da Real e Benemerita Sociedade Portuguesa de Beneficência in São Paulo. Later that same year, another device was installed and put into operation at the Santa Casa de Misericórdia do Rio de Janeiro (CARVALHO, 2007).

The CT device consists of four subsystems: electronic (power supply block and motion control devices), mechanical (responsible for the external structure and pneumatic devices), X-ray generator (emitting radiation in a fan-shaped pattern with specific high-power tubes and a self-cooling system), and informatics (responsible for process automation control, data acquisition, and image production, storage, and printing). Additionally, the equipment can be divided into gantry, table, and control panel, representing three distinct modules (NOBREGA, 2018).

The CT scanner enables the generation of images in anatomical sections with the support of a computer. During image processing, an X-ray tube, moving in a circular or semi-circular motion around the patient, emits radiation. Subsequently, strategically positioned detectors capture the radiation passing through the patient. The information collected by the detectors is converted into a digital signal and transmitted to the computer, where it is transformed into a grayscale image ranging from white to black (MOURÃO, 2015).

In tomographic imaging, structures in the body with increased radiological density, such as bones, are represented clearly and referred to as hyperdense, while less dense structures appear dark and are referred to as hypodense, such as air (DA SILVA; DE OLIVEIRA, 2017).

The CT is a painless procedure for the patient, who must remain still and lie on a table for several minutes until the examination is complete, allowing the device to capture the necessary images of the examined area (JUCHEM; DALL'AGNOL; MAGALHÃES, 2004).

II. Contrast and Its Applicability

The use of substances to enhance the visualization of internal structures in the body through radiological images has a long history, dating back approximately half a century (PINHO et al., 2009).

Contrast agents are radiopaque compounds, meaning they do not allow X-rays to pass through them, and therefore, they are employed to enhance the visualization of anatomical structures in diagnostic imaging procedures. Examples of contrast agents include barium sulfate, fluorescein, gadolinium, and iodinated contrast agents (FELIX; MALAMAN; ENSINA, 2013).



Organs that are close together, with similar density and average atomic numbers, do not naturally produce contrast during the evaluation of radiological images, making it challenging to differentiate them. Therefore, the use of contrast is indispensable to create contrast between structures that are not easily distinguishable (MENDES et al., 2022).

III. Iodinated Contrast

In CT, iodinated contrasts are used and administered prior to the examination either orally or intravenously. Iodinated contrast agents are sterile solutions containing iodine in their structure, the high atomic weight of iodine determines radiodensity, leading to an increased contrast between adjacent tissues. The basic structure of iodinated contrast agents is characterized by the presence of a benzene ring and three iodine molecules, while the side chains are modified by attaching hydroxyl groups or other molecules, thereby determining their distinctive properties (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

These compounds can be classified as ionic or non-ionic, depending on the degree of dissociation. When negatively and positively charged particles separate in a solution, it is termed ionic contrast, and when there is no release of electrically charged particles, it is considered non-ionic. Meanwhile, the osmolality is indicated by the higher concentration of particles in relation to the volume of the solution, thus, ionic contrast has higher osmolality. The viscosity and density of the contrast are also considered and affect the substance's flow in the bloodstream (JUCHEM; DALL'AGNOL; MAGALHÃES, 2004).

The ionic contrast agents have a meglumine or sodium (Na^+) cation in their structure, which is water-soluble. Upon contact with a solution, they dissociate into positive and negative ions that subsequently interact with water ions. On the other hand, non-ionic contrasts do not dissociate when in contact with the solution, making them water-soluble due to their electrically polar OH group (RODRIGUES, 2011).

Research suggests that non-ionic iodinated contrast offers greater safety compared to ionic iodinated contrast. This is because it has lower osmolality and lacks electrically charged particles when dissociated in solution, characteristics that contribute to better patient tolerance (JUCHEM; DALL'AGNOL; MAGALHÃES, 2004).

It is important to note that the osmolality of iodinated contrast is not only related to its dissociation in water but also depends on the size of the molecule and the concentration of iodine in it. Therefore, the tolerance of ionic contrast agents is determined based on its proximity to the osmolality of organic solutions, which is approximately 300 mOsm/kg (SANTOS et al., 2009).

One of the most important attributes of iodinated contrast is the ratio between the quantity of iodine atoms and the number of particles dissociated in a solution. This property is directly related to its contrast capacity (linked to the number of iodine atoms) and its toxic and hemodynamic effects (linked to the number of particles). Therefore, the higher the number of particles, the higher the osmolality of the contrast medium, resulting in increased toxic and hemodynamic effects (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

As shown in Table 1, iodinated contrast agents can be classified into three groups concerning the number of osmotically active particles essential for carrying iodine to tissues: iso-osmolar (iodine: particles ratio = 6), hypo-osmolar (iodine: particles ratio = 3 / low osmolality), and hyperosmolar (iodine: particles ratio = 1.5 / high osmolality) (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

I - Contrast Agents Classified in Relation to Osmolality

Groups	mOsm/Kg	Contrast agents
Alta osmolalidade ou HOCM (<i>high-osmolality contrast media</i>)	≥ 1500	Ionic monomers
Baixa osmolalidade ou LOCM (<i>low-osmolality contrast media</i>)	300 – 900	Non-ionic monomers and ionic dimers
Iso-osmolares ou IOCM (<i>iso-osmolality contrast media</i>)	280-290 / Similar to blood	Non-ionic dimers

Source: Author's own work, 2023



Iodinated contrast agents with a tri-iodinated benzene ring are termed monomers, while those with two benzene rings linked to an organic functional group are considered dimers (Table 2) (FELIX; MALAMAN; ENSINA, 2013).

In the structure of the contrast agent, three iodine atoms are released for each benzene ring. Therefore, non-ionic contrast agents identified as dimers have a higher concentration of iodine and consequently reduced osmolality (CREMONINI, 2010).

The viscosity of the iodinated contrast agent depends on the size and molecular structure, as well as temperature and iodine concentration. The importance of viscosity is related to the force required for intravenous administration through a needle or catheter, respecting the determined and safe speed limit for the patient. The dilution of the contrast agent in the blood is also influenced by viscosity, causing a variation in the final contrast of the obtained image (SANTOS et al., 2009).

Iso-osmolar compounds are considered the most viscous, with high osmolality contrast agents having smaller molecules and posing less risk of aggregation than low osmolality ones (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

IV. Pharmacokinetics and Pharmacodynamics

The pharmacokinetics of iodinated contrast agents can be outlined through a bi-compartmental model, formed by plasma and the interstitial space (extravascular and extracellular). Upon administration of the contrast agent, there is an increase in plasma concentration, leading to the transfer of the contrast agent to the interstitium. This, in turn, results in a reduction in plasma concentration. At a certain point in the process, there will be equality in the increase in interstitial concentration and the decrease in plasma concentration, resulting in a physiological and transient equilibrium, with no exchange between these compartments (Figure 1) (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

The iodinated contrast is primarily excreted by the kidneys in an intact form, not binding to plasma or serum proteins. Additionally, there is no significant metabolism, deiodination, or biotransformation (OPTIRAY, 2006).

Due to renal excretion, the plasma concentration decreases, causing the gradient to reverse, and the contrast agent is transported from the interstitium to the plasma until it is completely eliminated through glomerular filtration (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

Approximately 100% of intravenously administered iodinated contrast is excreted within 24 hours in patients with normal renal function (OMNIPAQUE, 2004).

The plasma concentration of iodine peaks immediately after the administration of the contrast, with blood levels decreasing slightly between 5 and 10 minutes and a half-life of about 20 minutes in vascular compartments (OPTIRAY, 2006).

After the intravenous injection, iodinated contrast can be observed in the renal parenchyma between 30 and 60 seconds. In patients with normalized renal function, opacification of the calyces and pelvis is detectable between 1 and 3 minutes, with excellent contrast occurring within 5 to 15 minutes (OPTIRAY, 2006).

V. Adverse Reactions

Adverse reactions to iodinated contrast agents frequently occur during computed tomography examinations, ranging from mild effects to more severe ones, posing a risk to the patient's life (JUCHEM; DALL'AGNOL, 2007).

Reactions induced by iodinated contrast agents can be characterized based on their temporality, severity, and physiopathological substrate. Concerning temporality, the reactions are subdivided into acute (occurring within one hour of contrast administration), delayed (occurring from one hour up to seven days after administration), and very delayed (occurring one week after contrast use) (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).

According to severity, reactions can be classified as mild, when symptoms do not progress and are self-limiting, moderate, presenting more pronounced symptoms requiring pharmacological treatment and with the potential to progress to a more delicate state, and severe reactions that pose a risk of death to the patient, necessitating hospitalization (POZZOBON; DA TRINDADE, 2017).

In terms of physiopathology, there are two major groups: reactions of non-hypersensitivity, caused by the pharmacological toxicity of the contrast agent used in the process, and hypersensitivity reactions that exhibit common characteristics of an allergic reaction, i.e., they are immunomediated (Figure 4) (SOCIEDADE PAULISTA DE RADIOLOGIA E DIAGNÓSTICO POR IMAGEM, 2020).



VI. Renal System and Key Biomarkers

The kidneys function is to maintain the homeostasis of blood and other extracellular bodily fluids, preserving purity and chemical constancy. For that to happen, it eliminates toxins, metabolic waste, excess water, and ions from the body through urine, while directing essential substances present in the filtered fluid back into the bloodstream (MARIEB; WILHELM; MALLATT, 2014).

Urine is produced through three processes: glomerular filtration, tubular reabsorption, and tubular secretion. During the glomerular filtration, a blood filtrate containing smaller molecules from blood plasma is transported from the glomerular capillaries to the renal tubule, where it is transformed into urine during its passage. In the tubular reabsorption, essential substances such as water, ions, and nutrients are reclaimed and directed back into the bloodstream from capillaries, while non-essential substances are accumulated for urine elimination. The process concludes with tubular secretion, actively directing more expendable molecules from the bloodstream to the tubule for elimination in urine (MARIEB; WILHELM; MALLATT, 2014).

The main waste products eliminated by the kidneys include urea, creatinine, and uric acid. The urea is a substance derived from the breakdown of amino acids in the liver and is found in higher quantities. The creatinine is formed by the breakdown, mainly in skeletal tissue, of phosphocreatine, a substance with high energy content and an important factor for muscle contraction. Uric acid, on the other hand, results from the recycling of nitrogenous bases (MATINI et al., 2014).

The assessment of renal activity is crucial for the diagnosis or monitoring of renal issues that can lead to impairment in various organs (DUSSE et al., 2017). Therefore, biomarkers are substances used for diagnosis, preventing the exacerbated progression of the pathology (BORGES; DE ALMEIDA, 2019).

With the advancement of technology, many other biomarkers are being developed for the diagnosis of renal dysfunctions. However, the most commonly used ones currently are urea, creatinine, inulin, proteinuria, and albuminuria (DUSSE et al., 2017).

VII. Creatinine

The changes in renal activity can be detected early through the analysis of creatinine concentration in the blood, as it is eliminated almost entirely through the renal route, with 85% by glomerular filtration and 15% by tubular secretion. Due to these characteristics and its low cost and high availability, the assessment of creatinine has become widely used for studying renal function (MALTA et al., 2019).

Creatinine is a residual substance from creatine and phosphocreatine, originating from muscle metabolism. It can also be obtained through the ingestion of meat. About 98% of creatine remains in the muscles, and approximately 1.7% is metabolized into creatinine, which is rapidly eliminated by the kidneys. Its muscular production is nearly constant (DUSSE et al., 2017).

The serum creatinine measurement is used to assess glomerular filtration rate (GFR) due to various factors, including the fact that creatinine elimination from the body occurs almost throughout the day, and the determination of the substance in plasma or serum is simple (ABENSUR, 2018).

Despite its advantages, creatinine cannot be considered an exact marker due to analytical and pre-analytical limitations and interferences, because its production is influenced by age, sex, body surface area, and ethnicity (BRITO; OLIVEIRA; DA SILVA, 2016).

Glomerular filtration rate (GFR) is proven to be the most sensitive and specific marker for determining possible renal alterations, and its measurement is designated by creatinine clearance. However, it faces obstacles due to the difficulty in obtaining the correct material for analysis (24-hour urine) (BRITO; OLIVEIRA; DA SILVA, 2016).

Due to the limitations presented, mathematical equations based on serum creatinine were developed to reduce variations in determining glomerular filtration rate. Guidelines for chronic kidney disease management recommend the Modification of Diet in Renal Disease Study Group (MDRD) and the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equations for adults. These equations use serum creatinine levels, sex, age, and ethnicity as parameters to evaluate glomerular filtration rate (DA FONSECA, et al., 2022).

The MDRD was initially developed to assess patients with established chronic kidney disease (CKD). However, it has been widely used for individuals with any risk profile for cardiovascular diseases. Therefore, there is concern about the validity of this equation when not used in the original clinical context (FELISBERTO; NESI; SULDOSKI; DA SILVA, 2015). MDRD estimates



the glomerular filtration rate using variables such as serum creatinine, age, race, and gender, with the aim of analyzing alterations caused by muscle mass (BRITO; OLIVEIRA; DA SILVA, 2016).

The CKD-EPI was created as a variation of the MDRD formula, including people with and without chronic kidney disease. The equation also uses variables such as serum creatinine, age, race, and gender to determine glomerular filtration rate. However, it performs better and has a higher accuracy in results than MDRD (BRITO; OLIVEIRA; DA SILVA, 2016).

The formulas used for calculating the equations are as follows:

MDRD: $GFR (ml/min/1.73 m^2) = 186 \times (Cr)^{1.154} \times (Age)^{0.203} \times 1.212 \text{ (African-American)} \times 0.742 \text{ (Female)}$

CKD-EPI: $GFR (ml/min/1.73 m^2) = 141 \times \min (Cr/k, 1)^{\alpha} \times \max (Cr/k, 1)^{1.209} \times 0.993^{Age} \times 1.018 \text{ [Female]} \times 1.159 \text{ [African-American]}$

Where: GFR - Glomerular Filtration Rate; Cr - Serum Creatinine; k is 0.7 for women and 0.9 for men; α : - 0.329 for women and - 0.411 for men; min: minimum of serum creatinine or 1; max: maximum of serum creatinine or 1 (FELISBERTO; NESI; SULDOSKI; DA SILVA, 2015).

Normal serum creatinine values in Brazil for males range from around 0.7 mg/dL to 1.2 mg/dL, while for females, it fluctuates between 0.5 mg/dL and 1.0 mg/dL (SZWARCOWALD, et al., 2019). Creatinine excretion in urine varies between 20-25 mg/kg weight/24 hours for men and 15-20 mg/kg weight/24 hours for women (DA FONSECA, et al., 2022).

VIII. Methodology

This study is characterized as an integrative literature review. This is the broadest methodological approach related to reviews, as it allows the inclusion of both experimental and non-experimental research for a more comprehensive understanding of the topic under analysis. Through this characterization, it is also possible to combine data from theoretical and empirical literature, adding a range of purposes, including defining concepts, reviewing theories and evidence, and analyzing methodological problems in a particular topic (DE SOUZA; DA SILVA; DE CARVALHO, 2010).

For this scientific research, searches were conducted in databases such as PubMed/MEDLINE, BVS (Biblioteca Virtual de Saúde), and ScienceDirect, in Portuguese and English languages, to gather scientific articles addressing hydration protocols for patients with altered creatinine during contrast-enhanced computed tomography between the years 2017 and 2023.

The following descriptors were used in the database searches: "Hydration protocols," "Computed tomography," "Intravenous contrast." These terms were searched on the "Descritores em Ciências da Saúde (DECS)" website. The Boolean operator used was "AND."

The inclusion criteria adopted were articles and journals available in full, addressing the studied topic, and published within the last 6 years. The exclusion criteria included articles published before the specified time frame, as well as articles focusing only on contrast administration in other types of imaging exams.

Sixteen articles were found in the PubMed database; however, after analysis regarding the specified period (2017-2022), language (English and Portuguese), and the addressed topic, only 3 articles remained. Additionally, 209 articles were found in ScienceDirect, and after applying the exclusion criteria, 6 were selected. The same process was carried out with BVS, where 2 articles were found but were excluded after analysis (Table 3).

Regarding the planning of this article, the methodology used was precise in achieving the objectives and addressing the research question of interest. Thus, after conducting literature searches in the selected databases, 224 studies were found, but only 9 were used as they aligned with the inclusion criteria.

IX. Results and Discussion

The intravenous contrast-enhanced computed tomography is a clinically significant diagnostic tool for various pathologies. To ensure access to this service for a larger number of people, it is crucial to maintain safety and necessary precautions for all types of patients, including those with altered creatinine due to renal dysfunction. Therefore, discussing hydration protocols for these patients is essential to ensure the benefits of CT procedures and reduce risks.

Despite the challenges posed by altered serum creatinine in patients, the administration of intravenous contrast remains important and necessary. For example, intravenous contrast-enhanced CT is crucial for oncology patients as it allows proper



characterization and staging of the disease, monitoring the immune response to the treatment, and evaluating disease progression or recurrence (COSMAI et al., 2020).

Notoriously, contrast enables the identification of tumors in the body, characterizing their vascularity, degrees of cystic changes, and necrosis. For tumors with no enhancement in their center caused by the contrast, it may signify necrosis or even cyst formation. Despite being rare, calcifications in malignant or benign tumors can also be diagnosed. For these reasons, the use of intravenous contrast-enhanced CT is indispensable (AHMED et al., 2023).

Hydration is a crucial method for preventing contrast-induced acute kidney injury, considered the gold standard. The hydration protects the expansion of the circulating volume compared to vasoconstriction caused by contrast administration, and it facilitates diuresis, preventing the substance from causing greater toxicity upon direct contact with renal tubular cells (ORLACCHIO et al., 2022).

Research presented by Orlacchio et al. (2022) demonstrates that for patients at moderate risk of developing post-contrast acute kidney injury, intravenous hydration is the recommended prevention method, using 1.4% sodium bicarbonate at a rate of 3 ml/kg/h for 1 hour before contrast administration or saline solution at 1 ml/kg/h for 3 to 4 hours before and 4 to 6 hours after contrast administration.

In a study, Laforcade et al. (2021) emphasize the need for a rigorous evaluation when prescribing hydration before administering iodinated contrast, especially for patients with cardiovascular disease or advanced chronic kidney disease, to adjust infusion rate, administered volume, and post-procedure monitoring.

Numerous studies were analyzed comparing hydration with saline solution and sodium bicarbonate. In the context of computed tomography, hydration with bicarbonate was found to be superior, whereas in relation to arteriography, the use of saline solution was reported to be more advantageous (LAFORCADE et al., 2021).

In contrast, the review by Walker et al. (2022) presented four studies comparing the use of sodium bicarbonate to a control group receiving intravenous normal saline. The comparison results showed that bicarbonate did not significantly reduce the need for renal replacement therapy in patients undergoing intravenous iodinated contrast administration.

It is important to note that the researchers acknowledge that sodium bicarbonate reduces the incidence of contrast-induced nephropathy (CIN) as it reduces free radicals by increasing tubular pH in a dose-dependent manner. Therefore, it is possible that the dose of bicarbonate used in the analyzed studies was not sufficient to produce results regarding renal injury, or the substance may not be effective against CIN when related to intravenous contrast administration (WALKER et al., 2022).

In the study presented by Nijssen et al. (2018), 660 patients undergoing intravenous iodinated contrast procedures were selected to receive either no prophylaxis (332 patients) or prophylactic intravenous hydration (328 patients). They were monitored for a period of 2 to 6 days, 26 to 35 days, and long-term post-contrast exposure, approximately 180 to 450 days. After 365 days, the need for dialysis was recorded in 2 patients who received prophylaxis and 2 who did not. Regarding serum creatinine, concentration levels increased significantly in both groups, but there was an estimated non-significant difference between the groups in the long term.

These findings suggest that there are no significant negative consequences if there is a discontinuation of prophylactic hydration; however, studies with a larger sample size would provide greater certainty regarding this assertion. Thus, the study proposes that the non-administration of prophylaxis is safe, even in the long term, as long as the optimal administration of contrast is respected and conducted in an elective setting (NIJSSEN et al., 2018).

The study conducted by WEE et al. (2021) involved 226 patients scheduled for administration of hydration prior to undergoing intravenous contrast-enhanced computed tomography examinations. Patients with an estimated glomerular filtration rate (eGFR) equivalent to 30-44 mL/min/1.73 m² were recommended an intravenous infusion of 250 mL of normal saline before and after the imaging procedure, each lasting over half an hour. Conversely, patients with an eGFR greater than approximately 45-60 mL/min/1.73 m² received a 500 mL bottle of mineral water and were advised to consume as much as possible before the examination, with the remainder after the imaging. An intravenous-oral combination was permitted to complete the 500 mL.

The results of this study were significant, showing that the risk of contrast-induced nephropathy is reduced when using a hydration protocol in patients, iodinated contrast with low osmolality, and discontinuing nephrotoxic drugs. Notably, when the patient has a higher baseline glomerular filtration rate, indicating normal renal function, they are protected after contrast administration, suggesting that hydration may not be necessary in patients with eGFR of 45-59 mL/min/1.73 m². Regarding the



administration form of the hydration protocol, the initial results indicated a disadvantage of intravenous hydration compared to oral hydration. However, this outcome can be explained by the fact that patients who underwent intravenous hydration inherently had worse renal function compared to others (WEE et al., 2021).

In contrast, the study by Sebastião et al. (2021) demonstrated no significant difference in the effectiveness of oral and intravenous hydration protocols. Based on 228 patients, 114 underwent oral hydration and 114 intravenous hydration. After the examination, the incidence rates of post-contrast acute kidney injury were 4.4% (oral) and 5.3% (intravenous). The data show the effectiveness of both protocols in preventing contrast-induced nephropathy.

In oncology patients, the study by Cosmai et al. (2020) demonstrated that hydration dosage recommended was 1–3 mL/kg/hour, initiated between 2 and 12 hours before intravenous contrast-enhanced CT. According to the hydration route, there was parity in effectiveness, meaning that oral administration is as safe and efficient as intravenous administration. Therefore, if intravenous hydration is not possible, oral hydration is recommended.

Pioli et al. (2023) presented important information regarding the hydration protocol for patients at the Cardiac Catheterization Laboratory of the University Hospital of Campinas (UNICAMP). Until 2015, patients at higher risk of contrast-induced nephropathy were admitted to the clinic to receive intravenous hydration with 0.9% saline at 1 mL/kg/h for 24 hours before the exam, during the procedure, and 12 hours after. After 2016, to overcome public health system challenges such as a lack of hospital beds, the laboratory directors changed the protocol to ambulatory oral hydration, allowing patients not to be hospitalized. The protocol involved instructing patients to drink 2 liters of water at home, 24 hours before and 24 hours after iodinated contrast-enhanced CT.

In this research, 116 patients susceptible to developing contrast-induced nephropathy (altered creatinine) participated, with 58 undergoing intravenous hydration and the other 58 receiving oral hydration. It was highlighted that oral hydration can be as effective as intravenous hydration in preventing the development of contrast-induced nephropathy. Only 7 out of 58 in the oral hydration group developed contrast-induced nephropathy, while 9 out of 58 in the intravenous hydration group developed the condition. This approach reduces hospital costs and allows for fewer hospitalizations. Creatinine serum concentration was also observed in the study, with 6 patients undergoing intravenous hydration experiencing an increase in creatinine, while only 3 in the oral hydration group had an increase (PIOLI et al., 2023).

In summary, the results presented in this monograph highlight the importance of using a hydration protocol before performing intravenous contrast-enhanced computed tomography, especially when the patient has altered serum creatinine, as also indicated by the glomerular filtration rate. Therefore, further engagement from researchers is needed to better understand the advantages of hydration protocols, ensuring the evolution of methods and materials used.

According to Silva-Batalha and Melleiro (2016), patient safety is considered a fundamental and complex component for healthcare organizations' quality. Therefore, correlating with the present study, constant research is needed for the diagnosis and evaluation of possible adverse effects caused by iodinated contrast, as well as the formulation and improvement of procedures that will contribute to the safety of patients undergoing computed tomography.

Through this monograph, it was possible to analyze that each healthcare institution employs its own hydration protocol, indicating a lack of standardization. Therefore, there is a need to standardize protocols for the prevention of contrast-induced nephropathy with the goal to provide professionals in the field with broader knowledge on the subject, facilitating the advancement of their work across various healthcare units.

This study has limitations due to the small number of available articles that specifically address the topic studied, reporting not only the administration of intravenous contrast in computed tomography but also hydration protocols for patients with altered creatinine.

X. Conclusion

The current article highlights the importance of hydration protocols for patients with altered creatinine levels undergoing intravenous contrast-enhanced computed tomography examinations.

With the literature review, it becomes evident that the effectiveness of both oral and intravenous hydration significantly influences the reduction of contrast-induced nephropathy prevalence in patients predisposed to its development.



Furthermore, it was feasible to emphasize the importance of using intravenous contrast in CT imaging protocols. Its administration allows for the diagnosis of various pathologies, including cancer, tumors, pulmonary thromboembolism, among others, and is essential even for patients with some form of renal dysfunction.

Therefore, there is a need to continually advance research efforts with the aim of enabling a greater number of patients with renal dysfunction to undergo CT with intravenous contrast safely and effectively. This allows for the early diagnosis of diseases and the monitoring of existing conditions.

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