Nociception During Iodinated Contrast Medium Infusion in Computed Tomography: Neurophysiological Mechanisms and Clinical Implications

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Abstract

This article reviews the neurophysiological mechanisms underlying nociception during the infusion of iodinated contrast media (ICM) in computed tomography (CT). It describes how rapid hemodynamic and osmotic changes activate vascular nociceptors, generating transient sensations such as intense warmth, urinary urgency, metallic taste, dry mouth, and mild discomfort or pain. Although these responses do not correspond to true pathological pain, they can influence patient comfort and, indirectly, image quality. The paper also discusses differential diagnosis and management strategies—including pre-procedural education, environmental reassurance, and adjustment of injection parameters—to mitigate these transient manifestations and optimize diagnostic outcomes.

Introduction

Iodinated contrast media (ICM) are routinely used in computed tomography (CT) to enhance vascular and tissue contrast, thereby improving diagnostic accuracy [1]. However, the rapid infusion of ICM can provoke a range of transient sensory phenomena [2] [3]. Patients may experience sensations such as intense warmth, urinary urgency, metallic taste, dry mouth, and mild discomfort or pain. While these sensations are not indicative of pathological pain, they can negatively affect patient compliance and, in some cases, the quality of CT images due to motion artifacts or altered vascular timing. Understanding the neurophysiological basis of these responses is crucial for distinguishing benign nociceptive phenomena from true adverse reactions and for implementing appropriate patient management strategies [3].

Materials and Methods

A comprehensive review of the literature was performed to analyze the mechanisms of nociception during ICM infusion. The process began with a literature search in databases such as PubMed, Scopus, and Web of Science, focusing on studies and reviews addressing the hemodynamic and osmotic changes induced by ICM, the activation of vascular nociceptors, and the subsequent neurophysiological pathways [5]. Articles discussing the processes of transduction, transmission, modulation, and perception of nociceptive signals, as well as clinical studies on the patient's sensory experience during contrast injection, were selected. Information regarding the activation of Aδ and C nerve fibers, the modulation of nociceptive signals by psychological factors such as anxiety and fear, and the impact of these processes on image quality and patient comfort was systematically extracted and synthesized [5].

Key Findings

The literature review confirms that nociception during the infusion of iodinated contrast media in CT is a transient, benign phenomenon driven primarily by rapid hemodynamic and osmotic changes. First, vascular nociceptors are activated (transduction), by chemical, mechanical, and terminal variations induced by the contrast medium. Second, the transmission of nociceptive signals occurs through two distinct nerve fiber types: fast-conducting Aδ fibers, which mediate well-localized sensations such as intense warmth or a pricking feeling, and slower C fibers, responsible for diffuse sensations of general discomfort or pressure [2]. Third, the modulation of these signals at spinal and cortical levels, influenced by emotional factors like anxiety and fear, can either amplify or dampen the final perception . Consequently, the subjective experience (perception) of these signals leads to transient symptoms—including intense warmth, urinary urgency, metallic taste, dry mouth, and mild discomfort—that may impact patient comfort and indirectly affect image quality due to movement artifacts [6]. Finally, effective patient management strategies such as pre-procedural education, a reassuring clinical environment, and adjustment of injection parameters are essential to minimize these effects and optimize diagnostic outcomes

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Results

The literature maintained that the injection of iodinated contrast media in computed tomography is a transient, innocuous process caused by sudden hemodynamic and osmotic changes [7]. In detail, results can be schematized as follows: First, the process of transduction was observed as the initial excitation of vascular nociceptors. Examinations indicated that chemical, mechanical, and temperature alterations caused by the contrast agent lead to sudden changes in intravascular volume and extreme vasodilation in highly perfused regions such as the face, neck, and pelvis [7]. Such stimuli play a vital role in inducing subsequent steps of the nociceptive process. Second, the transmission phase involves the conduction of nociceptive signals through various nerve fiber types. The literature suggests that quickly conducting Aδ fibers mediate well-localized sensations, usually perceived as severe warmth or stinging, whereas slower C fibers mediate diffuse sensations of generalized discomfort or pressure [7]. This dual mechanism likely explains the variability in sensory experiences reported by patients. Third, the modulation of nociceptive signals occurs in the spinal cord and higher brain structures, such as the thalamus, cortex, and limbic system [5]. Various studies have shown that psychological factors like fear and anxiety can lower the perception threshold for these signals, whereas endogenous inhibitory mechanisms, such as those of the opioid system, can decrease signal intensity. This modulation ultimately shapes the perception of the stimulus, which is highly subjective and dependent on the patient's emotional state. Clinically, these neurophysiological mechanisms manifest as transient symptoms during ICM injection. Patients commonly report sensations of warmth due to vasodilation and increased perfusion, urinary urgency due to enhanced pelvic blood flow, a metallic taste due to transient changes in gustatory sensitivity, dry mouth (xerostomia) due to osmotic effects on the salivary glands, and mild discomfort or pain along the infused vein's path [7]. Additionally, while the nociceptive response itself does not directly affect CT images, patient discomfort may result in motion artifacts or altered vascular timing, potentially compromising image quality.Finally, the results highlight the importance of specific patient management strategies. Pre-procedural education, a calm and reassuring clinical environment, and, when necessary, adjustments to injection parameters—such as reducing the injection rate—have been identified as critical measures to minimize the transient sensory effects of ICM injection [4]. Experience suggests that optimizing injection parameters, such as lowering the injection rate (from 4 mL/s to 3.0–2.5 mL/s) and using iso-osmolar or high-concentration agents, can help reduce patient discomfort while ensuring satisfactory opacification for CT imaging.

Discussion

The distinction between nociception—the detection of a noxious stimulus—and the subjective perception of pain is crucial in the clinical interpretation of reactions during ICM infusion [7]. The transient sensory phenomena observed are primarily attributable to rapid vascular and osmotic changes rather than true pathological pain or allergic responses [7]. Recognizing this difference is vital to avoid unnecessary diagnostic or therapeutic interventions . Furthermore, the modulation of nociceptive signals by emotional factors, notably anxiety, underscores the importance of a patient-centred approach . Pre-procedural education and a reassuring clinical environment can significantly reduce patient distress, thereby minimizing involuntary movements that may degrade image quality . Adjustments in the infusion rate, when possible, further contribute to a more comfortable experience without compromising the diagnostic utility of the CT study . The findings suggest that optimizing patient management protocols by addressing both the physiological and psychological components of the response can lead to improved patient compliance and higher-quality imaging outcomes . Future research may focus on refining contrast injection protocols and exploring additional interventions such as anxiolytic premedication to further alleviate these transient sensations . The study is a literature review rather than an empirical investigation. Future research could benefit from direct patient studies. The paper does not address whether demographic factors (e.g., age, sex, pre-existing conditions) influence the nociceptive response.

Conclusions

In conclusion, nociception during iodinated contrast medium infusion is a transient and generally benign phenomenon resulting from osmotic and vascular changes that activate nociceptors. Although these responses do not equate to true pathological pain, they can cause discomfort and potentially impact image quality. A comprehensive, patient-centred approach—including clear pre-exam communication, a reassuring environment, and appropriate modulation of injection parameters—can effectively mitigate these sensory manifestations and enhance overall diagnostic efficacy. In particular, optimizing injection parameters is critical: an elevated injection rate can accentuate the sensation of warmth and pain. Reducing the injection rate, for example from 4 mL/s to 3.0–2.5 mL/s, may decrease patient discomfort while still ensuring adequate iodine delivery for proper opacification. Moreover, the intrinsic characteristics of the contrast medium play a key role; iso-osmolar agents like iodixanol, with an osmolarity similar to blood and a favorable iodine atom-to-particle ratio, tend to cause less irritation than low-osmolar contrast media. Additionally, the use of high-concentration agents (e.g., 400 mg I/mL) enables a reduction in the injection rate while maintaining the necessary iodine dose, thereby improving tolerability in patients with fragile venous access. In addition to these technical adjustments, some evidence supports the use of pre-procedural anxiolytics to help modulate patient anxiety, which in turn may lower the threshold for nociceptive perception [7] .This aspect is particularly relevant in body CT examinations, where motion artifacts and difficulties in maintaining breath-hold can significantly compromise diagnostic interpretation. Continued research is warranted to further optimize these management strategies and improve patient outcomes in CT imaging [7].

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