

# The use of the gold compound (AuCl<sub>4</sub>) solution as an alternative contrast medium for iodine in computed tomography (CT-Scan) imaging

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## ABSTRACT

In computerized tomography (CT-Scan), iodine solution was used as a contrast medium to improve imaging. But the iodine solution has different side effects for patients. In the present work, one of the gold compounds AuCl<sub>4</sub> was used as an alternative contrast agent. The study used rabbits in an in vivo method to examine both the organs of the heart and the kidneys. Hounsfield unit (HU) values from computed tomography of rabbit and kidney angiography findings were found and compared with HU values for iodine contrast medium.

Iodine solution is the only contrast medium currently used in the present study, gold tetrachloride (AuCl<sub>4</sub>) solution has been chosen as an alternative contrast medium in computed tomography scanning (CT-scan). It was found that using AuCl<sub>4</sub> solution as an alternative contrast medium in rabbits enhanced the CT-scan imaging in the resolution and increasing the of heart and kidney organs in comparison with the iodine compound without any side effects.

Rabbit's heart and kidney were selected to study the effect of using 1.4 M iodine solution and 0.1 M AuCl<sub>4</sub> as an alternative contrast medium in CT-scan. The HU value for the heart has 53 HU when used high concentration of iodine complex, while the HU value at low concentration of alternative contrast medium of 0.1 M of gold compound has 50.5. The same results were found in the kidney organ. From these results, the resolution of the CT image is good and cleared when an alternative contrast medium (AuCl<sub>4</sub>) used. We can conclude that the alternate contrast medium for AuCl<sub>4</sub> solution has high HU values for both heart and kidney compared to iodine solution.

**Keywords:** AuCl<sub>4</sub> solution, contrast medium of CT-scan, heart of rabbit, kidney of rabbit, hounsfield unit, iodine solution

## INTRODUCTION

It is necessary to use contrast media in diagnosing by computed tomography to raise the clarity of the image, and iodine compounds are used as the only contrast. Despite the annoying side effects in the patient, but there is no option to use iodine associated with problems that lead to not using the contrast in some time for the diagnosis despite the lack of clarity of the image. Scientists have been finding alternatives to iodine in some studies [1-7].

Computed tomography (CT) is one of the most popular medical imaging modalities due to its high resolution images, fast scanning time, low cost, and compatibility with all patients. Soft tissue CT scans

require localization of contrast agents on imaging to create contrast and reveal anatomical information. Gold nanoparticles (AuNP) have recently attracted attention for their use in computerized tomography (CT CA) due to their high X-ray attenuation, simple surface chemistry and biocompatibility [8].

Gold compound has recently been proposed as an alternative to iodine-based contrast agents (iodine-CA) for computed tomography angiography. The objectives of this study were to confirm the appropriate environment for the evaluation of these new contrast agents, to verify the comparative variance of iodine-CA versus the gold compound to determine the optimal survey criteria for the gold compound [9].

CT scan is a non-invasive clinical diagnostic tool that allows 3D optical reconstruction and segmentation of tissues of interest. Thus a series of attenuation profiles or projections is obtained. In-depth description of the engineering principles is underlying modern tomography tools. The diagnostic imaging modality related to CT scans is X-ray endoscopy. Fluoroscopy allows obtaining continuous, real-time images of internal organs. As in computed tomography, imaging agents are often used in fluoroscopy to obtain better contrast resolution [10].

Diagnostic angiography and vascular interventions routinely use iodinated contrast material (ICM). Patients with renal disease or contrast sensitivity impose restrictions on the use of ICM. In such cases, alternative contrast media may be used to carry out the procedure. Current alternatives include carbon dioxide, gadolinium, and dilute ICM. Each of these alternatives has its own unique features and limitations. In the current review article, current alternatives to ICM are explored, with an emphasis on their respective applications and limitations [11].

They often select the most appropriate diagnostic tests to order their patients. It is essential to know the types of contrast agents, their risks, contraindications, and common clinical scenarios in which contrast-enhanced CT is appropriate. Several types of contrast agents can be used in a CT scan: oral, venous, rectal, and intrathecal [12].

Radiological contrast media (RCM) are prescription drugs used to improve the visibility of internal organs and structures in X-ray imaging techniques. They may have side effects ranging from itching to a life-threatening emergency, known as contrast-induced nephropathy (CIN). We define CIN as acute renal failure that occurs within 24-72 hours of exposure to RCM and cannot be attributed to other causes [13].

The results showed that gold nanoparticles at all concentrations and energies from 80 to 130 kV display a higher image-to-noise contrast ratio (CNR) than the iodized contrast medium. The CNR of the image was increased by increasing kVp and mAs. The maximum CNR value was 80 and 130 kV for the iodinated compounds and gold nanoparticles, respectively. The CNR value of gold nanoparticles at 130 kV and 200 mA was approximately five times higher than that of the iodized compounds [14,15].

In this study, gold tetrachloride solution is used as an alternative contrast medium for determination of rabbit organs by CT-scan technique.

## EXPERIMENTAL

### Materials

Bayer Pharma AG Company from the German company (Berlin Germany) Iodine contrast as Iopromide (Ultravist 370) was used as contrast media in

CT-scan. Gold tetrachloride ( $\text{AuCl}_4$ ) was purchased from sigma-Aldrich (England). Anesthesia materials used to anesthetize animals such as ketamine 10% from Alfasan Company (Holland), and xylazine 2% from Alfasan (Holland). Chemicals and solvents were used as received by the manufacturers. Deionized water was used to prepare aqueous solutions.

### Preparation of gold tetrachloride 0.1 M $\text{AuCl}_4$

A 0.1 molar solution of pure gold tetrachloride was prepared in a 10 ml volumetric flask, and the crystals were dissolved in deionized water to obtain a 0.1 molar solution of gold tetrachloride which used as alternative contrast medium.

### CT-Scan apparatuses

The CT-Scan screw type General Electric (GE) model TC Revolution EVO 128 Slices, GE Healthcare.

After preparing the rabbit for examination and in the case of anesthesia with the specified dose of the contrast, the rabbit was lying on the examination table to perform the spiral CT-Scan as shown in Figure 1.



FIGURE 1. preparation the rabbit in CT-scan

## RESULTS AND DISCUSSION

The CT-Scan technique is one of the methods used in the radiological diagnosis of various diseases. To enhance the accuracy of CT imaging, iodine solution is used as injectable contrast media. X-ray iodine attenuation is not effective in clinical computed tomography that uses high-energy X-rays. Because of these limitations, iodine-fortified nano-chemical contrast agents that can increase circulation time and reduce side effects have been developed in addition to Iodine [16]. CT-Scan study the rabbits were examined in a CT-Scan to checking the image of the heart, and kidney. The rabbits were divided into three groups;

The first group is the group that studied rabbits by CT-scan before (pre) using contrast media.

The second group was injected with different doses of iodine (350 mg/ml) contrast medium 1, 2, 3, 4, and 5 ml.

The third group was injected with different doses of alternative contrast medium of gold tetrachloride 0.1 M AuCl<sub>4</sub> solution 1, 2, 3, 4, and 5 ml, as in the following examinations:

**1. CT-Scan test of rabbit's heart**

This examination was taken for the heart organ of the rabbits before using any contrast media, the others injected with the iodine contrast (350 mg/ml) and with the alternative contrast AuCl<sub>4</sub> solution (0.1 M). The main factor which used to evaluation the resolution of imaging of CT-Scan is Hounsfield unit (HU) values. Hounsfield unit (HU): the absorption coefficient unit of the radiative transparency of a material; the normal value of HU for water is equal to = 0 HU, for air is = -1000 HU and for bone is equal to 1000 HU, the HU values are reported in CT for each case taken for the tested rabbits as in the following [17]:

The CT-scan imaging of the angiographic tests was taken to study the rabbits into three exams.

A. Checking the heart before using the contrast medium (native). It was found from the results as in Figure 2 of the heart of rabbit pre of contrast agent, and the value of the clarity of the heart of the HU value was 46.1 as illustrated in Table 1.

B. The CT-scan of the heart test with iodine contrast agent with HU values of heart organ have 53 when using the doses of 1 ml iodine (1.4 M), while, in the low dose of alternative contrast medium of 1 ml AuCl<sub>4</sub> (0.1 M) has 50.5 of HU value as show in Fig. 3.

C. Cardiac examination using alternative contrast medium of AuCl<sub>4</sub> (0.1 M) solution at different volume 2, 3, 4, and 5 ml which illustrated in Figure 4, 5, 6, and 7 were found an enhancement of the heart CT-scan imaging by higher HU values of 64.4, 70, 77.6, and 86.6 respectively, comparing with the HU values at iodine (1.4 M) with different volume 2, 3, 4, and 5ml have HU values of 62, 83, 95, and 146 respectively, as show in Table 1. The results discuss

that high HU value of the heart in low concentration of alternative contrast agent of 0.1 M AuCl<sub>4</sub> solution.

**2. CT-scan examination of rabbit's kidney**

The CT-scan imaging of the kidney organ was examined at three cases as in the following:

A. studies the kidney organ without using the contrast medium (native). It was found from the results that the HU value was 45.4 as illustrated in table 1 and Figure 2.

B. The CT-scan of kidney organ examination using an iodine contrast medium which has the HU values of 51, 70, 164, 190, and 235 when using the doses of iodine (1.4 M) volume of 1, 2, 3, 4, and 5 ml respectively as illustrated in Table 1.

C. kidney examination using alternative contrast medium of 0.1 M AuCl<sub>4</sub> solution at different volume of 1, 2, 3, 4, and 5 ml which illustrated in Figure 3, 4, 5, 6, and 7, it was found an enhancement of the kidney organ CT-scan imaging by higher HU values compering with the HU values at iodine and native case. Table 1 discusses the HU values when used alternative contrast agent of AuCl<sub>4</sub> solution of 50.1, 55.9, 60.4, 64.5, and 74 in the same order of the concentrations.

**TABLE 1.** HU values of heart and kidney of rabbits at different contrast media

Contrast medium	Dose (ml)	Heart (HU)	Kidney (HU)
Native	-	46.1	45.4
Iodine (1.4M)	1	53	51.0
	2	62	70
	3	83	164
	4	95	190
	5	146	235
AuCl <sub>4</sub> (0.1M)	1	50.5	50.1
	2	64.4	55.9
	3	70	60.4
	4	77.6	64.5
	5	86.6	74



**FIGURE 2.** CT-Scan imaging of the heart before using contrast media (Native)



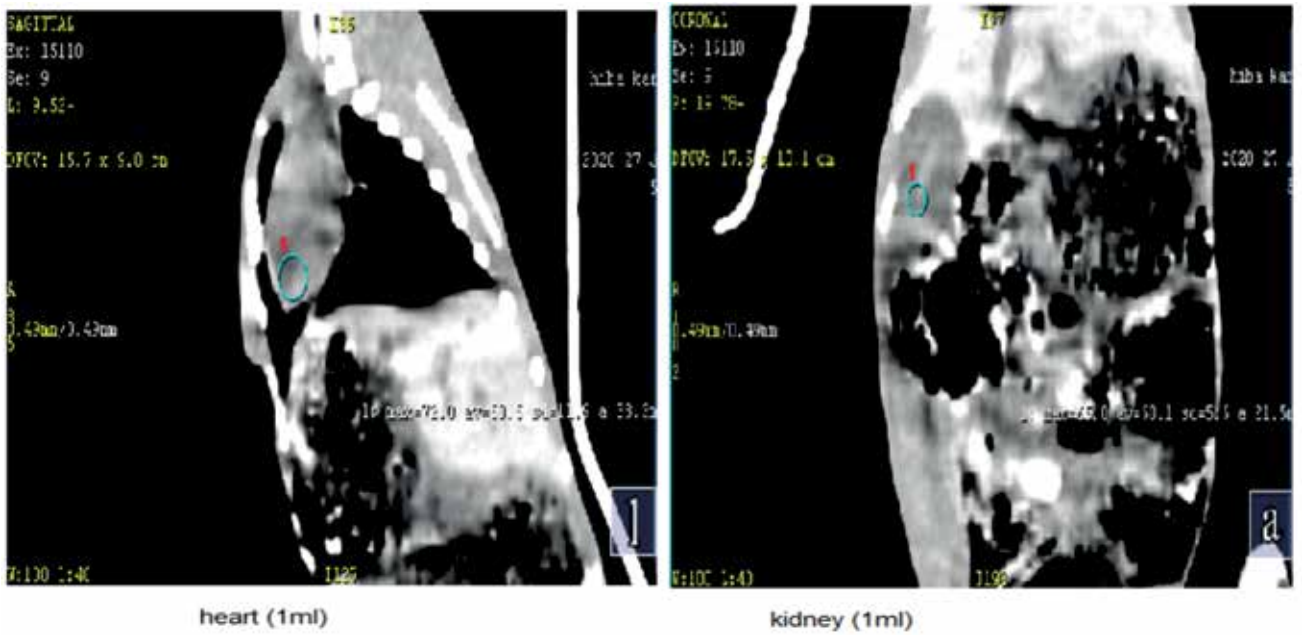


FIGURE 3. CT-Scan imaging of the heart after using contrast media (1 ml 0.1M AuCl<sub>4</sub>)

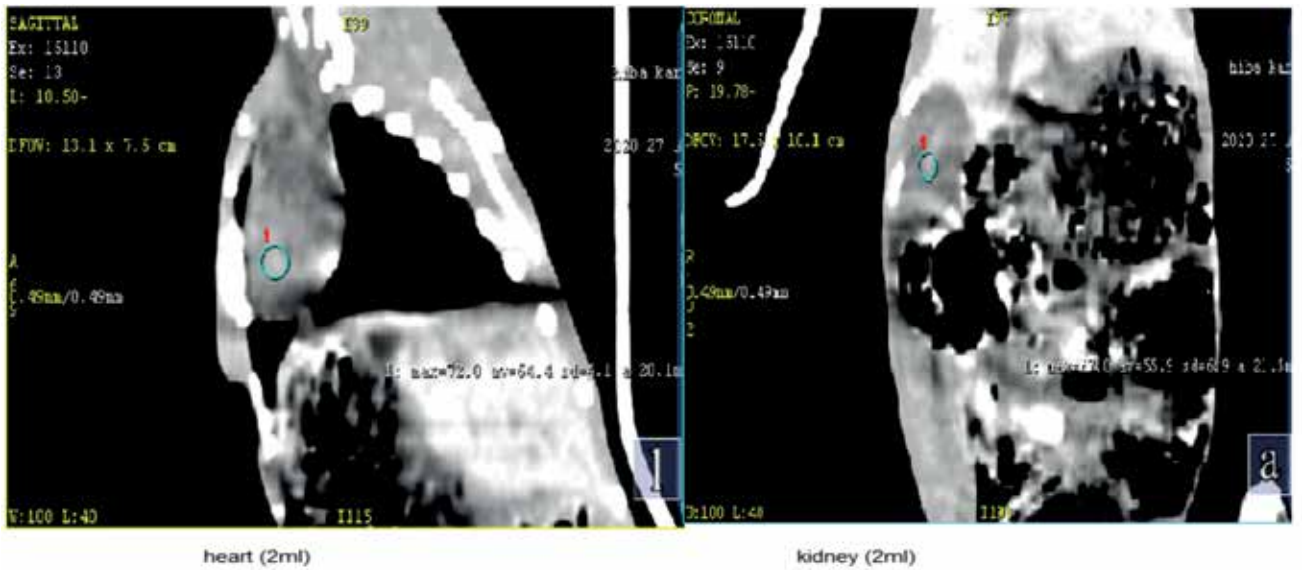


FIGURE 4. CT-Scan imaging of the heart after using contrast media (2 ml 0.1M AuCl<sub>4</sub>)

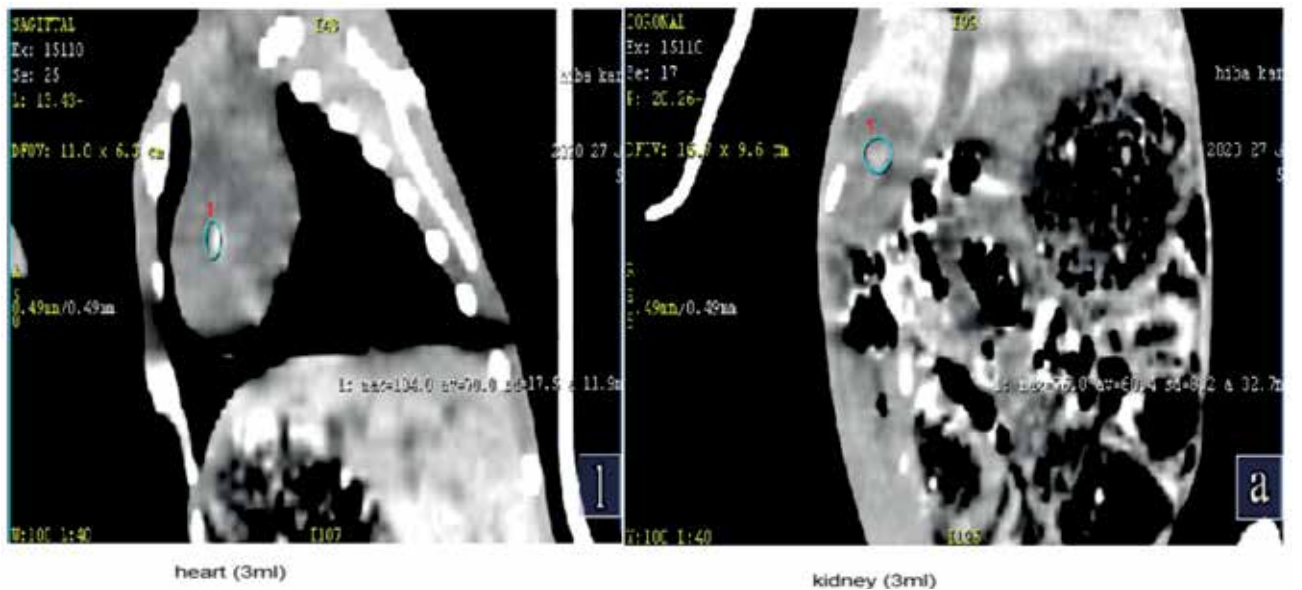


FIGURE 5. CT-Scan imaging of the heart after using contrast media (3 ml 0.1M AuCl<sub>4</sub>)



FIGURE 6. CT-Scan imaging of the heart after using contrast media (4 ml 0.1M AuCl<sub>4</sub>)

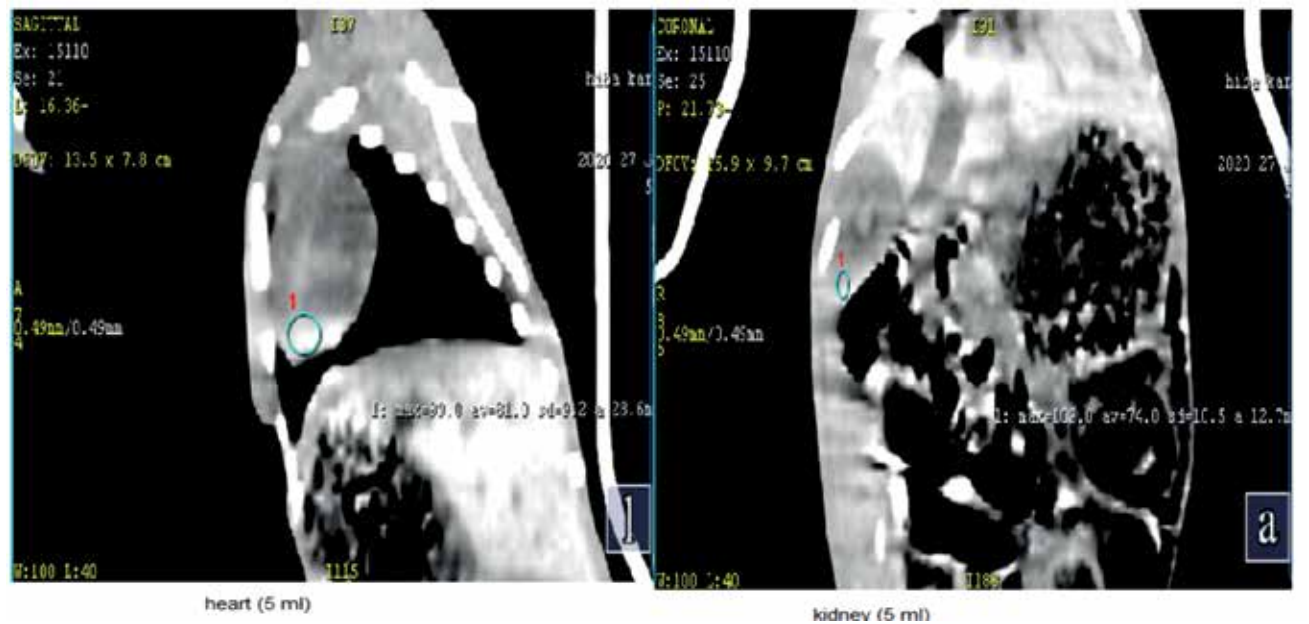


FIGURE 7. CT-Scan imaging of the heart after using contrast media (5 ml 0.1M AuCl<sub>4</sub>)

**CONCLUSIONS**

The gold solution is considered a safe compound to be used as an alternate contrast medium without any effect on the blood components in CT-scan diagnosis. AuCl<sub>4</sub> solution can be used as good alternative contrast due to the improved imaging to diagnose abdominal organs as in rabbit heart, and kidney. When using a different contrast medium, the Hounsfield unit values (HU) are very high

(AuCl<sub>4</sub>). The heart organ has a HU value of 50.5 at a dosage of 1 ml of 0.1 M of alternative contrast medium of gold compound, and 1 ml of the iodine (1.4 M) has a HU value of 53. Since CT scan resolution is higher in AuCl<sub>4</sub> solution than in iodine complex, and side effects are more severe in iodine complex but not in AuCl<sub>4</sub>, we recommend using AuCl<sub>4</sub> solution as an alternative contrast medium in CT-scan diagnosis.

*Conflict of interest:* none declared  
*Financial support:* none declared

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