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Design and Development of an Isothermal-Based Contrast Media Storage Device for Optimal Temperature Stability

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Abstract*:Contrast media are used in radiological diagnostic imaging to enhance the visibility of internal body structures. The storage of contrast media must adhere to temperature standards, specifically around 37°C, to maintain its quality. The use of inadequate storage equipment can lead to crystallization or a decrease in the function of the contrast medium. This research aims to design and build an automatic contrast media storage device, test its functionality, and evaluate its performance based on applicable storage standards. This research uses an exploratory approach. The designed tool is in the shape of a square box, made of plywood with an aluminum coating on the outside and leads on the inside. The main elements include an electric heater, a digital thermostat for temperature control, and LED lights for illumination. Function tests are conducted using a checklist assessment, while performance tests are evaluated based on ease of use, safety, and effectiveness. The results of the functional test demonstrate that every part of the apparatus, including the temperature controller and heating element, functions effectively to keep the contrast media temperature at 37°C. The equipment is safe, efficient, and easy to use, according to the performance test findings. A > 80% feasibility level was achieved in both experiments. The automatic contrast media storage device's design and construction were successful in preserving the contrast media's quality, boosting radiographers' productivity, and making it appropriate for use in medical facilities. However, in rooms with air conditioning, the device's effectiveness is subpar. To enhance the device's performance in different environmental circumstances, more development is required.*

Keywords: Contrast Media, Temperature Control, Radiology, Electronic Systems, Digital Thermostat

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INTRODUCTION

Contrast agents are compounds used to enhance the visibility of internal structures in medical diagnostic imaging. Contrast agents are used in X-ray imaging to increase the attenuation power of the X-rays (the material

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positive contrast) or reduce the power of X-rays (negative contrast material with air or gas base) (Owens et al., nd). There are various types of contrast media based on the material, one of which is iodine-based contrast media. Non-ionic contrast media is a solution of water-soluble substances (Puasa et al., 2012).

However, the higher iodine concentration (300 mg I/mL) than that achieved at normal solubility levels makes it a highly saturated solution (Imelda, 2023; Info, 2022). Highly saturated solutions have an intrinsic tendency to undergo spontaneous crystallization under rare circumstances (Octavia, 2024). This can be caused by, among other things, transportation conditions (shaking) (Kwiatkowski et al., 2026). From manufacture to use, the safety of non-ionic x-ray contrast agents depends heavily on the highest standards in production, transportation, storage, and handling of products, visual inspection, and aseptic techniques (Info, 2022; Manuscript et al., 2014).

The use of contrast media where short-term storage of contrast media should not be less than or more than 37°C, ensure the room temperature is not too cold which can cause the contrast media to crystallize and thicken (Kwiatkowski et al., 2026). The effect of temperature on osmolality clinically is that it can cause a burning sensation, discomfort, pain, and also electrolyte imbalance in children (Steels et al., 2018). Storage areas are subject to stock rotation on a scale, patient safety is also an important aspect that must not be overlooked (Manuscript et al., 2014).

In addition to patient safety, the development of an isothermal-based contrast media storage system is also urgent for hospital services (Dewilza & Yudha, 2023). Many healthcare facilities, particularly regional hospitals and radiology services with limited resources, still lack standard contrast media storage or heating equipment. This situation results in conventional contrast media storage without proper temperature monitoring. This research is important because it can produce appropriate technological innovations that are simpler, more economical, and easier to implement in various healthcare facilities (Akbar et al., 2022). The developed isothermal system also has the potential to improve the efficiency of radiology services by streamlining the contrast media injection process, reducing examination failures, and improving the quality of diagnostic imaging (S. Yudha et al., 2025).

Contrast media storage is a crucial aspect of radiology services because its quality is significantly affected by its storage temperature stability. Uncontrolled temperature changes can lead to increased viscosity, changes in homogeneity, and even decreased contrast media quality, potentially affecting diagnostic imaging results (S. Yudha et al., 2026). Contrast media that is too cold can also increase injection pressure, increase the risk of extravasation, and cause patient discomfort (Puasa et al., 2012). Therefore, an isothermal storage system is needed to maintain a stable contrast media temperature so that the safety and effectiveness of contrast media use can be optimally maintained.

METHODOLOGY

The research design used in the isothermal-based contrast media storage study is a true experimental design with a quantitative approach. The research was conducted experimentally in a laboratory or radiology installation using measuring instruments in the form of digital temperature sensors, thermometers, and viscometers to obtain objective data regarding the performance of the isothermal system.(Sugiyono, 2019;S. ;Nerifa D. diki isnardi Yudha, 2023).

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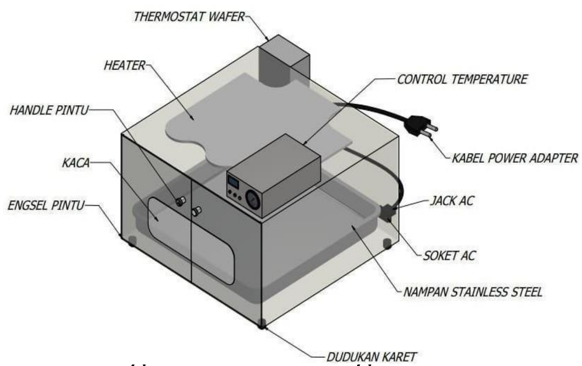
This research design was chosen because it is able to provide a stronger picture of the cause-effect relationship regarding the influence of the use of an isothermal storage system on the quality of contrast media and the efficiency of radiology services.(Silaen et al., 2021;Steels et al., 2018). In addition, this design is also suitable for research into the development of applied technology that is oriented towards innovation in medical devices in the field of radiology.(Notoadmojo, 2020;Kwiatkowski et al., 2026).

Tools and materials

The equipment used in this study were a wood saw, iron cutting tool, ruler, electric soldering iron, glue gun, screwdriver set, nails, water thermostat, temperature control, door handle, door hinge, clear glass, limit switch, AC socket, DC socket, AC jack, power adapter cable, cassette holder, tin, LED light.

Research Steps

1. Designing a tool begins with sketching the design from various angles, such as the front, side, and top views. This design is used to determine the size, shape, and layout of components that meet the tool's functional requirements.



2. The tool is designed with a length of 45 cm and a height of 30 cm so that it can accommodate several bottles of contrast media at once.
3. The structure of the tool is designed to consist of several layers of material, namely multiplex as the main frame, aluminum as a temperature-leveling layer and lead (Pb) as an additional protective layer which functions to retain heat, prevent corrosion and maintain temperature stability.(Sagita Yudha M.Tr.Kes. et al., 2025)The combination of these three materials aims to create isothermal conditions, namely maintaining a stable temperature inside the container despite changes in the surrounding temperature and acting as a barrier to scattered radiation.

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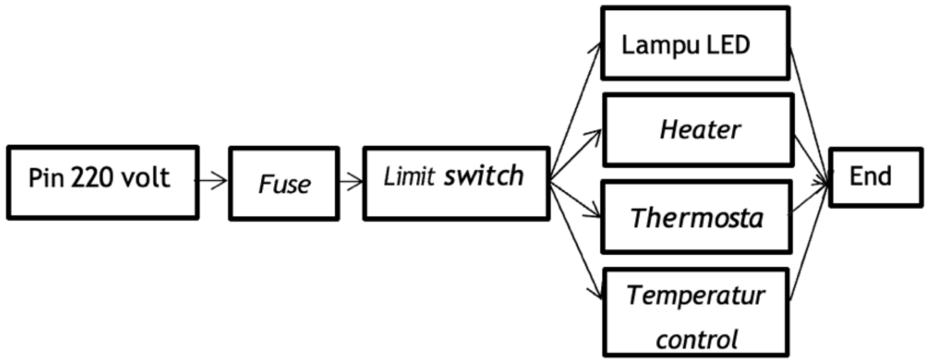

Figure 2. Schematic diagram of the electrical circuit

Data analysis

A. Testingtool

1. Plug the jack into the wall socket.
2. Turn the switch button "ON".
3. Set the desired standard temperature
4. Observe whether the temperature in the contrast media storage box is standard or not using a thermometer/temperature control.
5. Insert contrast media if the temperature inside the box is according to standards.

B. Performance Test

Handing over the checklist sheet to respondents for analysis(Oktavia Puspita Sari., 2023). The performance test was given to respondents with questions, then the data was processed as follows:

1. If the respondent's answer supports the feasibility of designing a contrast media storage facility, then each question is worth one point.
2. If the respondent's answer does not support the feasibility of the design and construction of the contrast media storage area, then each question is worth zero points.
3. Then the data obtained is evaluated in the following way:

Data analysis was conducted based on the results of performance and functional tests on the design of the contrast media storage facility. In the performance test, the design is declared unfeasible if the assessment percentage is less than 75%. Conversely, if the assessment percentage reaches more than 75%, the design of the contrast media storage facility is declared suitable for use. Meanwhile, in the functional test, the design of the iodine-based contrast media storage facility is declared to function properly if all components and systems work according to the design, as indicated by a success percentage approaching or reaching 100%. The higher the success

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percentage in the functional test, the better the level of reliability and feasibility of the developed device.

$$\frac{\text{Jumlah jawaban yang mendukung uji kelayakan}}{\text{Jumlah seluruh pertanyaan X Jumlah responden}} \quad \text{X} \quad 100\ \%$$

RESULTS AND DISCUSSION

Result

1. Results of the Design and Construction of a Contrast Media Storage Place

This contrast media storage container is constructed from rectangular plywood. The exterior is coated with aluminum, while the interior is lined with lead (Pb) for optimal protection. The container is equipped with a heating element, LED lights for illumination, and a temperature sensor connected to a temperature controller located on top. This structure is designed to support efficient storage functionality. Weighing approximately 3 kg, this container can hold approximately 60 pieces of contrast media. The following image illustrates the design:

Figure 4.1 Front View of the Tool

Figure 4.2 Top View of the Tool

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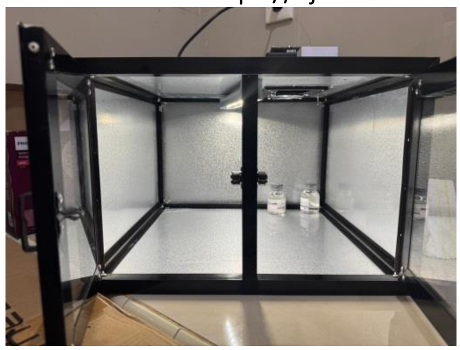

Figure 4.3 Internal View of the Tool

The parts in the contrast media storage area are as follows:

a. Box frame
The storage frame was designed using 5mm thick plywood, cut to dimensions of 30 cm long, 40 cm wide, and 30 cm high. The cutting was done using a cutter to the specified dimensions. Before installing the aluminum on the outer surface, the plywood was first coated with glue to ensure perfect adhesion, resulting in a strong and durable structure. Then, aluminum foil was added.

b. Heating Element
The heating element used is a heater, which works on a similar principle to the heating elements in irons and magic jars. This component is made of wire coated with mica (mica paper) that can conduct electricity, generating heat. In contrast media storage areas, this heating element is installed above the inside of the box.

Discussion

This research successfully developed a contrast media storage design based on an isothermal system capable of maintaining the contrast media temperature at around 37°C, in accordance with the recommended storage temperature for iodine-based contrast media. This success was demonstrated by the results of functional and performance tests, which obtained a feasibility score of over 80%, thus deeming the device suitable for use as a storage medium in radiology installations.

The ability of the device to maintain temperature is a very important aspect because the physical characteristics of contrast media are greatly influenced by storage temperature.(Gbande et al., 2023)Iodine contrast media is a supersaturated solution, potentially subject to crystallization if stored at too low a temperature. Furthermore, lowering the temperature will increase the viscosity of the contrast media, requiring higher injection pressures, increasing the risk of extravasation, and causing patient discomfort.(Imelda, 2023). Therefore, the success of the device in maintaining the temperature at 37°C indicates that the developed isothermal system is capable of maintaining the physical stability of the contrast medium so that its quality is maintained.

This success is influenced by several main components that work in an integrated manner, namely the heating element (heater), a digital thermostat as an automatic temperature controller,

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and the use of an aluminum layer that helps distribute heat more evenly in the storage space.(Bangun et al., 2018)The use of a digital thermostat automatically maintains the temperature at a preset value, minimizing fluctuations. This system is superior to conventional storage, which relies solely on room temperature without continuous monitoring or temperature control.(Taylor et al., 2007).

Functional test results indicate that all device components, from the heater, temperature sensor, LED light, to the storage door mechanism, operate as designed. A success rate exceeding 80% indicates that the device design meets basic operational requirements for contrast media storage. These results align with the concept of developing simple medical devices, which emphasizes functionality, safety, and ease of operation as key indicators of a prototype's success.

Furthermore, performance test results showed that respondents considered the device easy to use, safe, and effective. The high easiness-of-use rating indicates that the component layout, temperature control system, and access to the contrast medium have been ergonomically designed. From a safety perspective, the use of an automatic temperature control system reduces the risk of overheating, which can damage the contrast medium. From an effectiveness perspective, the device can reduce preparation time before CT scans and radiology procedures that use contrast medium.(Dewilza & Yudha, 2023)(Puasa et al., 2012).

However, this study also found limitations. The device's performance decreased when used in rooms with relatively low ambient temperatures due to the use of air conditioning (AC). This condition causes heat loss to the environment to occur more rapidly, so the heating element takes longer to maintain the storage room temperature. This phenomenon indicates that the efficiency of the thermal insulation system used can still be improved by using insulation materials with lower thermal conductivity, adding a special insulating layer, or implementing a microcontroller-based temperature control system with a more adaptive control algorithm, such as a PID (Proportional-Integral-Derivative) system.(Taylor et al., 2007)(Steels et al., 2018).

From a clinical perspective, this device has significant potential for use in hospitals and radiology clinics that do not yet have commercial contrast warmers. Compared to relatively expensive commercial devices, this design offers a more economical alternative while still maintaining the contrast medium temperature according to radiology service standards.(Owens et al., nd). Thus, this device has the potential to increase service efficiency, maintain the quality of contrast media, reduce the risk of injection failure due to increased viscosity, and improve patient comfort during examination procedures.(Gbande et al., 2023).

Overall, the research results indicate that the developed isothermal-based contrast media storage system meets the requirements for functionality, ease of use, safety, and operational effectiveness. The feasibility level obtained in both functional and performance tests indicates that this device is suitable for use as an alternative contrast media storage system in radiology service facilities. However, further development is still needed, especially in the thermal insulation system and automatic temperature control to ensure optimal device performance under various environmental conditions..

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CONCLUSIONS

The rectangular contrast media storage container uses multiplex material coated with aluminum on the outside for structural strength and lead (Pb) on the inside for protection from scattered radiation. This device is equipped with a heating element, LED lights for lighting and a digital thermostat for temperature control. Functional tests showed that all components of the device work well, including the ability to reach and maintain a temperature of 37°C, according to contrast media storage standards. Performance tests showed that the device is easy to use, safe and effective in maintaining the quality of the contrast media. With functional and performance test results reaching a feasibility of > 80%, this device is proven to be able to meet operational needs in the field of radiography. The device is designed to support the work efficiency of radiographers, as well as protect the contrast media from environmental influences such as inappropriate temperatures.

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