Design and Application of a Disposable Medical Negative-Pressure Drainage Fluid Specimen Collection Device (Postprint)

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Date: 2023-03-06T00:00:00+00:00

Abstract

This paper describes the design and application method of a disposable medical negative-pressure drainage fluid specimen collection device, aiming to reduce the procedural steps for collecting drainage fluid specimens, save nursing operation time, and avoid false positives caused by multiple steps during the collection process.

Full Text

Preamble

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Title: Design and Application of a Disposable Negative Pressure Device for Collecting Drainage Fluid Specimens
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Abstract

This paper introduces the design and application of a disposable negative pressure device for collecting drainage fluid specimens. The purpose of this design is to streamline the process of specimen collection, reduce nursing workload, and avoid false-positive results caused by multiple contamination-prone steps in conventional methods.

Keywords: microbial culture; specimen collection; negative pressure device

Introduction

Microbial culture is widely used as a means of detecting pathogenic bacteria in clinical practice. Bacterial culture and antimicrobial susceptibility testing are rational bases for clinical antibiotic use. Correct specimen collection directly affects the positive rate and accuracy of pathogen culture and is the key to successful clinical microbiological testing. Research has confirmed that the primary factor affecting specimen testing quality is contamination, which arises from the cumbersome steps required during specimen collection for patients. The traditional method for collecting midstream culture specimens from drainage tubes involves disinfecting the rubber tube puncture site with alcohol twice, with a disinfection range of 5 cm and a 1-minute interval between applications, then extracting drainage fluid with a 5 mL syringe, sealing the needle, placing it in a disposable specimen container, and immediately sending it for testing. This process is highly susceptible to contamination, affecting test results. Therefore, collection tools, transport media, specimen containers, packaging, and transport procedures all influence microbial detection from drainage fluid. To address these issues, this paper reports the design and application of a disposable medical negative pressure drainage fluid specimen collection device (National Utility Model Patent No.: ZL 202020274916.0), which reduces operational steps and avoids factors that compromise drainage fluid culture results. This device eliminates the need for syringe extraction, preventing needlestick injuries; uses negative pressure to control collection volume; and allows direct transport after collection without requiring a dedicated sterile bottle, thereby avoiding secondary contamination.

1. Materials and Fabrication

The negative pressure drainage specimen collector consists of three main components: a squeeze ball, a tube (hidden within the ball), and a collection container [Figure 1: see original paper]. The upper and lower portions of the squeeze ball are equipped with a first one-way air valve and a second one-way air valve, respectively. The tube runs vertically through the ball, forming a drainage channel. The collection container is detachably connected to the lower part of the ball and communicates with the drainage channel.

Compared with existing technologies, this utility model effectively integrates the collection container with the negative pressure ball. The one-way valves on the upper and lower parts of the negative pressure ball form a valve structure.

When the negative pressure ball is squeezed [Figure 5: see original paper], the internal air pressure increases, forcing the first diaphragm upward and pressing the second diaphragm down. This opens the first air vent while closing the second, allowing gas to exit the ball unidirectionally through the first air vent and preventing drainage fluid backflow. When the ball is released [Figure 6: see original paper], it regains its shape, gradually reducing internal pressure. As the internal pressure falls below atmospheric pressure (both outside the ball and inside the collection container), the first diaphragm is pressed closed by atmospheric pressure while the second diaphragm is lifted, closing the first air vent and opening the second. This causes gas to flow unidirectionally from the collection container into the ball, creating negative pressure within the collection chamber and drawing drainage fluid through the drainage channel into the container.

The first one-way air valve comprises a first diaphragm [Figure 2: see original paper] and a first diaphragm fixing end formed on the upper part of the ball, along with a first air vent. The first diaphragm is slidably mounted on the fixing end to close or open the first air vent. The second one-way air valve includes a second diaphragm [Figure 3: see original paper] and a second diaphragm fixing end formed on the lower part of the ball, along with a second air vent. The second diaphragm is slidably mounted on its fixing end to close or open the second air vent. The tube runs vertically through the ball to form the drainage channel [Figure 4: see original paper]. The collection container includes a collection chamber and a sealing cap, which can be screw-connected to either the sealing cap or the ball, and is detachably connected to the lower part of the ball while communicating with the drainage channel [Figure 7: see original paper].

After specimen collection is complete, the sealing cap can be screwed on directly [Figure 4: see original paper], facilitating operation for medical staff, improving work efficiency, and effectively preventing contamination of collected specimens.

Advantages of this negative pressure drainage specimen collector compared with existing technologies and equipment:

1. No sharp instrument operation, preventing needlestick injuries;

2. Reduced operational steps for collecting drainage fluid culture specimens, avoiding impacts on culture results from multi-step procedures;

3. Negative pressure collection is convenient and easy to operate, with collection volume controlled by pressure, saving nursing operation time;

4. Direct transport after collection, allowing the microbiology laboratory to directly inoculate onto culture media according to requirements, avoiding secondary contamination from repeated opening of sterile containers.

In summary, this negative pressure drainage specimen collector reduces the steps required for drainage fluid specimen collection, saves nursing operation time, and avoids false-positive results caused by multiple contamination-prone steps in the collection process.

Conflict of Interest Statement: The authors declare no conflicts of interest.

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2. Usage Method

During use, first connect the sampling port connector [Figure 4: see original paper] to the drainage tube and screw the collection chamber onto the collector connector. Then squeeze the ball [Figure 5: see original paper], which increases pressure inside the ball and lifts the first diaphragm while pressing the second diaphragm down, opening the first air vent and closing the second. This allows gas inside the ball to exit unidirectionally through the first air vent. Next, release the ball [Figure 6: see original paper]; as the ball regains its shape, internal pressure gradually decreases. When internal pressure falls below atmospheric pressure (both external and within the collection chamber), the first diaphragm is pressed closed by atmospheric pressure while the second diaphragm is lifted, closing the first air vent and opening the second. This allows gas to flow unidirectionally from the collection chamber into the ball, creating negative pressure that draws drainage fluid through the drainage channel into the collection chamber. The ball can be squeezed repeatedly. After obtaining an appropriate specimen volume in the collection chamber, the sealing cap can be screwed on directly [Figure 4: see original paper] for subsequent processing. This effectively prevents contamination of collected specimens.

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3. Discussion

Unlike other laboratory tests that primarily rely on blood specimens, clinical microbiological testing has highly diverse specimen sources. Consequently, quality control for clinical microbiology is more complex, particularly during specimen collection, which can lead to unqualified specimens being submitted and affecting test accuracy and timeliness [1]. Specimen collection quality determines the final test results and indirectly influences clinical judgment and treatment of patients. Clinically, the focus is often on aseptic collection and transport, but standardized tools for specimen collection are lacking [2-4].

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Note: Figure translations are in progress. See original paper for figures.