Drying of endoscopes and its implication for microbial contamination: how safe is the use?

Secagem de endoscópios e sua implicação na contaminação microbiana: quão seguro é o uso?

Secado de endoscopios y sus implicaciones para la contaminación microbiana: ¿hasta qué punto es seguro su uso?

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ABSTRACT: Objective: To evaluate the drying practices employed in endoscopy facilities and determine the occurrence of microbiological growth in ready-to-use equipment. **Methods:** This is a cross-sectional study with the evaluation of the drying step of endoscopes in eight services of gastrointestinal endoscopy. The processing of 22 gastrointestinal endoscopes was monitored, and a microbiological evaluation was carried out in 60 endoscope channels after high-level disinfection and subsequent storage. **Results:** External drying was not carried out in 50.0% (11/22) of equipment after cleaning, and 27.2% (6/22) did not undergo internal drying of the channels. Contamination was detected in 21.9% (7/32) of the samples of stored endoscope channels, with microbial loads ranging from $2.0x10^1$ to $2.5x10^5$ CFU/mL. Furthermore, we identified microbial growth in 32.1% (9/28) of the channels after high-level disinfection, with microbial loads ranging from $<10^1$ to a maximum of $1.3x10^3$ CFU/mL. *Pseudomonas sp.* accounted for 50.0% (6/12) of isolated microorganisms found in endoscope channels. **Conclusion:** The presence of infectious agents associated with inadequate practices, especially during the drying step, evidently contributes to the maintenance of microbial contamination in endoscopes, posing risks to subsequent patients.

Keywords: Gastrointestinal endoscope. Infection control. Patient safety. Product storage. Equipment contamination.

RESUMO: Objetivo: Avaliar as práticas de secagem implementadas pelos serviços de endoscopia e determinar a ocorrência de crescimento microbiológico em equipamentos prontos para uso. **Métodos:** Trata-se de um estudo transversal, envolvendo a avaliação da etapa de secagem dos endoscópios em oito serviços de endoscopia gastrointestinal. O processamento de 22 endoscópios gastrointestinais foi monitorado, e uma avaliação microbiológica foi realizada em 60 canais de endoscópios após a desinfecção de alto nível e o armazenamento subsequente. **Resultados:** A secagem externa não foi realizada em 50,0% (11/22) dos equipamentos após a limpeza, e 27,2% (6/22) não passaram por secagem interna dos canais. A contaminação foi detectada em 21,9% (7/32) das amostras de canais de endoscópios armazenados, com cargas microbianas variando de 2,0x101 a 2,5x105 UFC/mL. Além disso, 32,1% (9/28) dos canais apresentaram crescimento microbiano após a desinfecção de alto nível, com cargas microbianas variando de <101 a um máximo de 1,3x103 UFC/mL. A *Pseudomonas sp.* foi responsável por 50,0% (6/12) dos micro-organismos isolados encontrados nos canais do endoscópio. **Conclusão:** A presença de agentes infecciosos associada às práticas inadequadas, especialmente durante a secagem, evidentemente contribui para a persistência da contaminação microbiana nos endoscópios, representando um risco para os pacientes subsequentes.

Palavras-chave: Endoscópio gastrointestinal. Controle de infecção. Segurança do paciente. Armazenamento de produtos. Contaminação de equipamentos.

RESUMEN: Objetivo: Evaluar las prácticas de secado implementadas por los servicios de endoscopia y determinar la ocurrencia de crecimiento microbiológico en equipos listos para su uso. **Métodos:** Se trata de un estudio transversal que evaluó la etapa de secado de los endoscopios en ocho servicios de endoscopia gastrointestinal. Se monitoreó el procesamiento de 22 endoscopios gastrointestinales, y se realizó una evaluación microbiológica en 60 canales de endoscopios tras la desinfección de alto nivel y el almacenamiento subsecuente. **Resultados:** El secado externo no fue realizado en el 50,0% (11/22) de los equipos tras la limpieza, y el 27,2% (6/22) no pasó por el secado interno de los canales. Se detectó contaminación en el 21,9% (7/32) de

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las muestras de canales de endoscopio almacenados, con cargas microbianas que variaron entre 2,0x101 y 2,5x105 UFC/mL. Además, el 32,1% (9/28) de los canales presentó crecimiento microbiano tras la desinfección de alto nivel, con cargas microbianas que variaron entre <101 y un máximo de 1,3x103 UFC/mL. *Pseudomonas sp.* fue responsable del 50,0% (6/12) de los microorganismos aislados encontrados en los canales de los endoscopios. **Conclusión:** La presencia de agentes infecciosos, asociada a prácticas inadecuadas, especialmente durante el secado, contribuye de manera evidente a la persistencia de la contaminación microbiana en los endoscopios, representando un riesgo para los pacientes subsecuentes.

Palabras clave: Endoscopio gastrointestinal. Control de infecciones. Seguridad del paciente. Almacenamiento de productos. Contaminación de equipos.

INTRODUCTION

Endoscopic procedures play a crucial role in the prevention of digestive diseases and the early detection of cancer[1]. However, the complex structure and long channels with narrow lumens in gastrointestinal endoscopes make their safe reuse challenging. Improper and inadequate reprocessing can result in the persistence of contamination, posing a significant risk to the user of such equipment[1-3]. Cross-contamination among patients undergoing these procedures has been reported in cases of reprocessing failures, leading to infectious outbreaks[4,5].

The reprocessing of endoscopes involves multiple interdependent steps, including pre-cleaning, transportation, leak testing, manual and automatic cleaning, rinsing, drying, high-level disinfection, drying again for ten minutes, and storage[2]. Effective controls at each stage are necessary to minimize the risk of equipment contamination after use[6]. The drying of equipment is of particular importance, as residual microorganisms or those carried by rinsing water can thrive in wet channels, potentially promoting biofilm formation[7,8].

Numerous studies investigating moisture retention in endoscope channels have highlighted the challenges associated with drying and its critical role in ensuring the safe use of endoscopes[9,10]. Thus, the drying procedure should not be underestimated and deserves significant attention.

This is also because the guidelines do not describe the drying steps in detail, which can lead to doubts and inadequate execution. In this context, an overview of how drying is performed in health services can help improve the execution of this step and reduce the risk of contamination of endoscopes, consequently improving safety in using this equipment.

Therefore, our study aimed to address the following question: What is the relationship between drying endoscopes after reprocessing and the maintenance of microbial contamination, and how does it impact the safety of this equipment for subsequent use?

OBJECTIVE

The objective of our study was to evaluate the drying practices employed in endoscopy facilities and determine the microbial growth in equipment intended for use at these establishments.

METHODS

The study was submitted to the Ethics Committee of the Federal University of Minas Gerais and approved under opinion 4.574.663. The reprocessing executors observed signed a consent form and were advised of the research objectives and risks.

This cross-sectional study was conducted in gastrointestinal endoscopy facilities within hospital settings in the city of Belo Horizonte, Minas Gerais state, Brazil. The facilities included in the study performed upper digestive endoscopy, colonoscopy, and duodenoscopy procedures. The study was conducted through a comprehensive analysis of the drying and storage stages of gastrointestinal endoscope processing, encompassing the three types of equipment: colonoscope, gastroscope, and duodenoscope. The inclusion of facilities performing duodenoscopy, a highly complex procedure typically conducted in hospitals, ensured a broader representation of different flexible gastrointestinal endoscopes.

The study population was defined by conducting a survey on the National Registry of Health Establishments (CNES, *Cadastro Nacional de Estabelecimentos de Saúde*). Subsequently, emails were sent to all identified establishments, requesting information on the profile of care and the average number of procedures conducted per month for each type of equipment. Based on this data, 18 facilities were identified as potentially eligible for the study.

Out of the 18 identified facilities, six declined participation due to the COVID-19 pandemic restrictions, one service

was undergoing a management change and was not open to research at the time, and three facilities did not provide visits within the study timeframe. Consequently, the final sample consisted of eight in-hospital endoscopy facilities.

Data collection occurred between February and June 2021 and involved observing the reprocessing practices of 22 different types of gastrointestinal endoscopes. Microbiological analysis was performed on 24 endoscopic equipment, resulting in 60 samples for microbiological culture from the air/water channels of all endoscopes and the elevator (duodenoscopes). Two ready-to-use endoscopes had samples taken; however, due to operational problems, the drying practices employed were not monitored.

An instrument based on scientific evidence and recommendations from national and international societies[11-14] was developed to assess the steps of manual and automated reprocessing and then applied to the participating facilities. To evaluate reprocessing effectiveness, the ready-to-use equipment underwent microbiological analysis using samples obtained from the air/water channels of all endoscopes and the elevator (duodenoscopes).

Samples from the stored equipment, regardless of packaging duration, were collected for analysis. Aseptic technique was employed for collecting samples from the air/water, using the channel with the highest amount of contaminants since it cannot be brushed in most models, and channels using the flush method, in which 40 mL of sterile bi-distilled water was injected into the channel[15]. The fluid obtained from the distal portion of the insertion tube was collected in a sterile container and sent for analysis[15]. The technique described in the Duodenoscope Surveillance Culture Sampling Manual was applied to obtain samples from the elevator canal, involving swabbing from all sides of the device (anterior and posterior)[16].

To ensure sample quality, a specific thermal box was used for packaging during transportation, maintaining refrigeration and temperature control. The samples were processed at the Central Public Health Laboratory of the State of Minas Gerais (Lacen-MG, Laboratório Central de Saúde Pública do Estado de Minas Gerais), under the coordination of the Ezequiel Dias Foundation. The bacteria (except mycobacteria) were identified by an automated method using the matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF-MS). The equipment VITEK-MS® from the company bioMérieux® was used. For sensitivity tests, the manual Kirby-Bauer method (disk diffusion method) was adopted, following the BrCAST criteria.

Data analysis consisted of descriptive statistics, including frequency distribution and measures of central tendency, utilizing the Stata 14 program.

RESULTS

The study included the participation of eight in-hospital endoscopy facilities located in Belo Horizonte city. In terms of the method employed for reprocessing endoscopes, half of the facilities used manual reprocessing, while the remaining facilities utilized a combination of manual and automated processes. The total number of endoscopes in the technological park of all participating facilities was 85, with an average of 10.6 devices per service (ranging from 5 to 18). On average, these facilities conducted 325 procedures per month (ranging from 53 to 735).

Within this context, we evaluated the reprocessing of 22 endoscopic equipment pieces, comprising eight gastroscopes, eight colonoscopes, and six duodenoscopes. Of these, 11 underwent manual high-level disinfection, while the remaining were subjected to automated disinfection. In the high-level disinfection process, the services used the following disinfectants: glutaraldehyde 2% and 50% (4/8) and orthophthalaldehyde 0.55% and 50% (4/8).

In the final rinsing step after manual high-level disinfection, 8 out of 11 equipment pieces were rinsed with tap water, while the remaining three were rinsed with reverse osmosis water. It is important to note that only 16 had their internal channels rinsed.

Table 1 exhibits a detailed analysis of the drying procedure for the endoscopes.

Among the equipment monitored, those submitted to automated reprocessing (n=11), distributed in four facilities, presented different automatic internal drying times: 54.5% (6/11) had a five-minute schedule and 45.5% (5/11) had only one minute.

One of the facilities visited had only the Automatic Endoscope Reprocessor (AER) drying and no pressurized air device for additional drying when necessary.

A critical point that deserves to be highlighted is that although drying before storage was an adherent practice in the reprocessing of the equipment observed 86.3% (19/22), none of them had a specific drying period or any criterion for verifying the effectiveness of this step.

As for the storage of endoscopes, the evaluation was performed in all eight facilities, which is described in Table 2.

Table 1. Analysis of the drying procedure after cleaning and before storage adopted in the equipment. Belo Horizonte (MG), Brazil, 2025.

Variables	After cleaning	Before storage
	Equipment % (N)	
External drying (n=22)		
Yes	50.0 (11)	100.0 (22)
No	**50.0 (11)**	0 (0)
Device used for external drying (n=11 | n=22)		
Surgical compress	72.7 (8)	86.3 (19)
Compressed air gun	27.2 (3)	13.6 (3)
Internal drying (n=22)		
Yes	72.7 (16)	86.3 (19)
No	**27.2 (6)**	**13.6 (3)**
The device used for internal drying (n=16 | n=19)		
Compressed air gun	81.2 (13)	84.2 (16)
Latex tube with compressed air	18.7 (3)	15.7 (3)
Drying endoscopes thoroughly using ≥10 minutes of forced air (n=22)		
No	Not applicable*	**100,0 (22)**
Flush with 70% alcohol in the channels, followed by drying with air under pressure (n=22)		
Yes	Not applicable†	72.7 (16)
No		27.2 (6)

*There is no set time recommendation for drying after cleaning in the guidelines; †Flushing with alcohol after cleaning is recommended only for final drying before storage.
Items in bold are intended to draw readers' attention to the most vulnerable points.

Table 2. Analysis of storage practices adopted in the facilities in the study. Belo Horizonte (MG), Brazil, 2025.

Variables	Facilities (n=8) % (n)
Exclusive cabinet for storage of endoscopes	
Yes	62.5 (5)
No	**37.5 (3)**
Storage cabinets for endoscopes with natural ventilation	
Yes	62.5 (5)
No	**37.5 (3)**
Position of equipment during storage	
Vertical	87.5 (7)
Horizontal	**12.5 (1)**
Valves connected to the endoscope during storage	
Yes	**25.0 (2)**
No	75.0 (6)

Items in bold are intended to draw readers' attention to the most vulnerable points.

No service used drying cabinets for storage, with airflow in the equipment channels.

Regarding the maximum time of storage of endoscopes, it was detected that half of the facilities (4/8) had a pre-established period, with 2.0% of them standardizing three days, and 60.0%, seven days for the equipment to be submitted to a new process in case of non-use.

As a result of the microbiological analysis performed, it was observed that 62.5% (5/8) of the facilities presented at least one contaminated piece of equipment. Among the 60 samples collected, 23.3% (14/60) presented positive cultures.

Thus, of the 32 samples obtained from stored equipment and 28 after reprocessing, 22.0% and 35.8%, respectively, showed growth of microorganisms—a total contamination rate of 26.6%. Table 3 shows the contamination rate according to equipment and time of collection.

Gastroscopes were the equipment that showed the most contamination, either after processing or after storage.

The microbial load of microorganisms was higher in the stored equipment, ranging from $2.0x10^1$ to $9.5x10^4$ CFU/mL, while after reprocessing, loads ranging from <10 to a maximum of $1.3x10^3$ CFU/mL were found.

Table 4 shows the details of the pathogens detected and their respective microbial loads, according to equipment and time of collection.

Table 3. Contamination frequency of stored and post-processed endoscopes according to the type of equipment and sampled channel. Belo Horizonte (MG), Brazil, 2025.

Collection time	Type of endoscope (channel sampled)	Samples collected (n=60)	Positive culture (n=16)	Contamination rate % (n)
Stored	Gastroscope (air-water channel)	8	3	37.5 (3/8)
	Colonoscope (air-water channel)	8	3	37.5 (3/8)
	Duodenoscope (air-water channel)	8	1	12.5 (1/8)
	Duodenoscope (elevator)	8	0	0 (0)
After reprocessing*	Gastroscope (air-water channel)	8	4	50.0 (4/8)
	Colonoscope (air-water channel)	8	2	25.0 (2/8)
	Duodenoscope (air-water channel)	6	2	33.3 (2/6)
	Duodenoscope (elevator)	6	1	16.6 (1/6)

*Collection performed immediately after reprocessing.

Bacteria of epidemiological importance, such as carbapenem-resistant *Enterobacteriaceae,* accounted for 33.3% (4/12) of the microorganisms isolated.

It was also found that 12 different species of microorganisms were recovered, and different species of *Pseudomonas* were recovered in all samples of stored equipment. Of these 12 species detected, 50.0% (6/12) drew attention — the varied species of *Pseudomonas*, especially *Pseudomonas chlororaphis*.

DISCUSSION

The drying of gastrointestinal endoscopes is a critical factor that affects the efficiency of their reprocessing and facilitates the formation of biofilms[7-8]. It is essential to perform external drying using a soft, lint-free cloth and to ensure airflow through the equipment channels using filtered air regulated under pressure after cleaning and before disinfection. These measures reduce the risk of water residue remaining in the equipment, which can cause the disinfectant solution to be diluted and consequently lose its effectiveness[2,11,12].

The reprocessing of endoscopes involves numerous complex and interdependent steps, with over 100 steps in total. These steps require human intervention, even in automated processes, which increases the likelihood of variations in practice execution and the possibility of steps being overlooked by professionals, thereby compromising the effectiveness of the endoscope reprocessing[17,18].

Furthermore, guidelines and recommendations on drying are often not sufficiently detailed, which can lead to omissions or negligence in executing this step in clinical practice[2,3,6,7,11,12]. Several studies have reported failures at various reprocessing steps, including drying. For instance, Barbosa et al.[19] found that 40.0% of the endoscopes evaluated in 20 institutions in Goiânia (GO), Brazil, were not subjected to external drying after cleaning and disinfection. In addition, 75.0% of working channels were not dried, and only 10.0% were dried using compressed air under pressure[19]. Another survey involving 249 different institutions reported that only 47.8% of centers practiced manual or automated forced air drying of working channels[20].

According to Ofstead et al.[10], drying is often disregarded by the operational team, which is consistent with the findings of this study, where insufficient adherence to drying was observed both after cleaning and before storage. A literature review of 18 studies from different countries identified drying failure as one of the most common gaps in the clinical practice of endoscope reprocessing[21].

The lack of infrastructure, such as the absence of a pressure air device in the cleaning room, further compounds the drying issue. Two of the visited facilities did not have such accessories, compromising the drying process. Additionally, some facilities used a 60 mL syringe for drying, which has been proven ineffective[22].

In cases where automated methods were employed, all automated endoscopic processors included a drying function in their programming, ranging from 1 to 5 minutes. However, this programming is optional, and often the drying cycle is very short, insufficient to completely dry the endoscope channels. A study has shown that a ten-minute automatic air injection schedule in the canals yields superior results compared to manual or five-minute automated drying, as assessed by researchers using a borescope to inspect the biopsy channels[23].

Table 4. Results of the microbiological analysis of samples from the air/water channels and elevator of endoscopes, according to type of equipment and time of collection. Belo Horizonte (MG), Brazil, 2025.

Equipment	Microorganism/resistance profile	Stored (n=32)		After reprocessing* (n=28)	
		Positive cultures (n=7) %	Microbial load (UFC/mL)	Positive cultures (n=9) %	Microbial load (UFC/mL)
Gastroscope	*Pseudomonas chlororaphis* Meropenem resistant	14.3	$1.3x10^5$	†	†
	Pseudomonas chlororaphis Sensitive Meropenem	†	†	11.1	<10
	Pseudomonas aeruginosa Pseudomonas putida, Acinetobacter seifertii Sensitive Imipenem	14.3	$9.5x10^{4‡}$	†	†
	Mycobacterium abscessus			11.1	§
	Pseudomonas sp	†	†	11.1	<10
	Escherichia coli sensitive Imipenem *Pseudomonas aeruginosa* Sensitive Meropenem *Serratia marcescens* Sensitive Meropenem, Ertapenem	14.3	$8.5x10^{3‡}$	†	†
Colonoscope	*Pseudomonas aeruginosa* Intermediary Imipenem	†	†	11.1	<10
	Escherichia coli, Klebsiella pneumoniae and *Kluyvera ascorbata* sensitive Meropenem e Ertapenem	14.3	$>2.5x10^5$	†	†
	Pseudomonas aeruginosa Meropenem sensitive *Pseudomonas chlororaphis* Meropenem resistant	14.3	$1.4x10^{3‡}$	†	†
	Stenotrophomonas maltophilia intermediate Sulfamethoxazole/ trimethoprim	†	†	11.1	$1.3x10^{3‡}$
	Pseudomonas putida Intermediary Imipenem *Serratia marcescens* Imipenem resistant	14.3	$2x10^{1‡}$	†	†
	Methylobacterium radiotolerans Sphingomonas melonis//	†	†	11.1	$3x10^{1‡}$
Duodenoscope (air-water channel)	*Pseudomonas chlororaphis* Imipenem resistant	14.3	$1.2x10^5$	†	†
	Pseudomonas chlororaphis Intermediary Imipenem	†	†	11.1	$1.0x10^1$
Duodenoscope (elevator)	*Mycobacterium tuberculosis*	†	†	11.1	§
	Pseudomonas chlororaphis Intermediary Imipenem	†	†	11.1	$2x10^1$

*Collection taken immediately after reprocessing; †There was no growth; ‡Sample with growth of more than one microorganism, the microbial load is equivalent to the whole; §Not measured; //Lack of standardization in literature for antibiograms.

However, the ten-minute duration may still be inadequate, especially for smaller diameter canals like air and water channels, requiring a longer duration of controlled pressure air injection[22,24].

Efficient drying of endoscopes, particularly their channels, is a widely discussed topic among researchers worldwide due to its fundamental role in ensuring reprocessing efficiency and safety[23-25]. The use of a borescope, a tool capable

of visualizing the interior of endoscope channels, has been recommended for monitoring drying effectiveness. However, the high cost of borescopes has limited their widespread use in endoscopy facilities.

Studies examining endoscopes stored with the aid of a borescope have identified significant percentages of equipment with fluid presence, reaching frequencies of up to 95.0% in evaluated endoscopes[9,10].

To facilitate drying, recommendations include performing a flush with 70% or 90% alcohol in the channels before storage, followed by airflow with filtered air under pressure[22]. However, the use of alcohol for drying is a controversial practice. Some studies indicate that it may not provide benefits and could even increase the drying time of endoscope channels[24,26]. Moreover, if drying is effective, the use of alcohol becomes unnecessary in terms of microbiological contamination[25].

Regarding limitations, the observational model used in this study was considered valuable for analyzing processes and routines. However, the "Hawthorne effect" may have occurred, which means that professionals may change their behavior due to the presence of an observer, since the researcher watched all the steps. This could have led to an overestimation of the quality of certain practices performed. To minimize this effect, the technicians involved in the reprocessing were not provided with detailed information about the specific items being evaluated. Nonetheless, despite identifying numerous process gaps, it is possible that there are even more in the day-to-day operations of the facilities.

In addition, due to the COVID-19 pandemic, the acceptance of invited facilities was affected, impacting the study's sample size and participation.

CONCLUSION

The study revealed that international scientific evidence and recommendations regarding endoscope drying, although scarce, have not been widely implemented in clinical practice by professionals in endoscopy facilities. This finding highlights critical aspects in the reprocessing of endoscopic equipment.

These findings emphasize the importance of addressing the gaps in drying practices and implementing appropriate measures to ensure the safety and effectiveness of endoscope reprocessing. Adequate drying is crucial for preventing the maintenance and spread of microbial contamination, ultimately safeguarding the well-being of patients.

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CONFLICT OF INTERESTS

The authors declare no conflicts of interest.

AUTHORS' CONTRIBUTION

RASM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – review & editing. NBG: Validation, Writing – original draft, Writing – review & editing. ACO: Conceptualization, Formal analysis, Supervision, Validation, Visualization, Writing – review & editing.

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