Challenges of Operationalizing a Mobile Computerized Tomography Unit: Experience Report from the ProPulmão Project

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The ProPulmão pilot project, launched in 2023, aimed to screen and analyze the epidemiological profile of lung cancer in remote communities across Bahia, Brazil, where access to imaging exams is limited. Recognizing the critical role of low-dose computed tomography (CT) in reducing lung cancer mortality, the project employed a mobile unit equipped with a 16-channel CT scanner and the necessary medical infrastructure to screen asymptomatic smokers and ex-smokers who had quit smoking up to 15 years ago. While the initiative proved effective, it encountered significant logistical challenges, particularly with internet connectivity and power supply—both essential for the consistent operation of the CT unit and the transmission and storage of medical images. Despite these obstacles, the project successfully facilitated early detection of lung cancer cases, underscoring the importance of such screening programs. The challenges led to refining work protocols, including improved image storage techniques, a deeper understanding of managing medical image servers, and enhanced communication between the technical and medical teams. These experiences contributed to the ProPulmão project's success. They provided valuable insights for implementing similar initiatives in other states across Brazil, thereby promoting greater accessibility and early detection in underserved areas.
Keywords: Lung Cancer. Screening. Computed Tomography. Accessibility.

Lung cancer, as highlighted by the Global Cancer Observatory (2022) [1], is the most prevalent malignancy worldwide, accounting for approximately 2.5 million new cases, which represents 12.4% of all cancer incidences.

A study by Lima Costa and colleagues (2020) [2] reveals a notable reduction in lung cancer mortality rates among men, dropping from 19.72 (2001-2005) to 12.62 (2026-2030). However, among women, the mortality rate is expected to increase from 7.62 (2001-2005) to 9.61 (2026-2030), with the southern region of Brazil showing the highest mortality rates.

The effectiveness of annual low-dose computed tomography (CT) screening in reducing lung cancer mortality by up to 20% was demonstrated by the National Lung Screening Trial (NLST) in 2011 [3]. This underscores the importance of three-dimensional imaging diagnostics for early detection of calcified nodules and lesions, particularly in vulnerable populations such as smokers and ex-smokers. Japan was among the first countries to implement a mobile CT unit for lung cancer screening in 1998 [4], and a similar initiative was developed in Barretos, São Paulo, Brazil, as described by Chiarantano and colleagues (2022) [5].

In Bahia, an epidemiological profile study by Chaves and colleagues (2022) [6] revealed that between 2018 and 2021, the state ranked 8th in the number of diagnoses of bronchial and lung cancer, with 1,620 cases, 1,097 of which were in the capital, Salvador. In this context, the ProPulmão pilot project was launched to develop a mobile CT unit to screen for lung cancer among vulnerable populations in remote areas of Bahia with limited access to diagnostic imaging. This initiative is crucial for transforming the landscape of lung cancer diagnosis and treatment in Brazil. However, operating such a mobile unit presents several challenges that must be addressed to ensure its success.

Materials and Methods

This study is a descriptive, qualitative experience report that emerged from the initiative to address the various challenges of operationalizing a mobile tomography unit and exploring possible

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solutions to optimize workflow. The project utilized a heavy transport vehicle equipped to carry a 16-channel Access Tomography model with technical parameters of 100 kV, 50 mAs, 92 mA, and a slice thickness of 2.00 mm. The vehicle was also adapted with the necessary medical infrastructure to ensure safe patient care and to perform lung tomography scans using minimal radiation doses while maintaining high-quality imaging (Figure 1).

Results and Discussion

The experience gained from the ProPulmão Pilot Project, particularly in the areas of image transmission, storage, and interpretation in each city across Bahia, highlighted several crucial and recurring challenges (Table 1).

These impacts highlight the critical need for reliable internet connectivity and robust data management protocols in mobile CT units, mainly when serving remote or underserved populations. The challenges experienced underscore the importance of addressing these technical issues to ensure that mobile health initiatives like ProPulmão can achieve their full potential in improving public health outcomes.

The internet connection has proven to be a critical factor in the success of the ProPulmão Pilot Project, as it is essential for the seamless sending, storage, and viewing of medical images. However, the connection's instability and unpredictability have posed significant challenges. We recommend the following solutions to address these issues:

External Support System: Implement an external storage system to complement the CT scanner's limited internal memory. This will prevent memory overload, which can impair the scanner's functionality, ensure continuous operation, and safeguard against data loss.

Protocol Development and Adaptation: Develop and adapt protocols that allow for comprehensive monitoring of the image transmission process from the mobile tomography unit to the server. This will help to ensure that images are correctly and promptly uploaded, minimizing the risk of data loss.

Figure 1. Service flow.

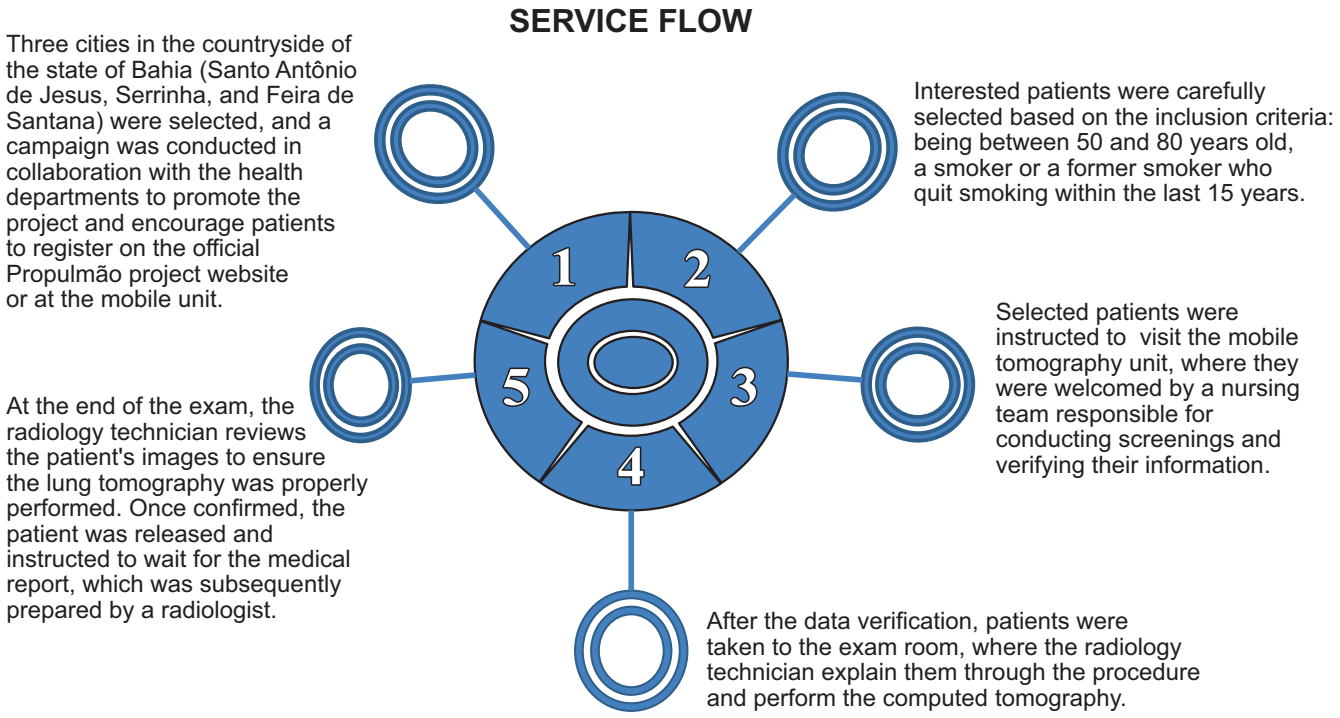

Table 1. Chanllenges and impacts the ProPulmão pilot project.

Challenges	Impacts
Patient Recruitment and Adherence Despite an active publicity campaign in collaboration with municipal and social organizations, patient recruitment in some interior cities of Bahia fell below expectations. This shortfall can be attributed to difficulties in patient transportation, limited internet access, and challenges in maintaining communication via mobile phone.	**Lack of Lung Lesions** The lack Detecting lung lesions in vulnerable populations prevents the accurate assessment of the profile of malignant lung disease in these communities.
Internet Connection Instability Unstable internet connections, particularly in remote areas, frequently impair the functioning of the server used for sending, storing, and viewing images. This instability posed significant challenges to maintaining the continuity and reliability of the imaging services provided by the mobile unit.	**Missed Diagnoses** Some exam images failed to upload to the server due to inadequate internet connectivity. This prevented radiologists from evaluating the images and releasing diagnostic reports. In the worst-case scenario, the loss of patient exams meant that crucial diagnostic opportunities were missed, potentially leaving lung lesions undetected.
Manual Data Entry Errors On days when the server was unavailable, manual scanning of patient data became necessary. However, this process was prone to errors, further complicating the workflow and potentially impacting the accuracy of patient records.	**Data Entry Errors** The CT scanner is the source of ionizing radiation and the system where patient data is registered. Under normal conditions, Wdata is automatically populated by typing a unique access code for each patient. However, on days when the internet connection was unstable, data had to be entered manually, leading to errors. These errors included mismatches in patient names on exam records, which could result in a medical report being issued under the wrong name, compromising patient safety and the accuracy of medical records.
Limited Internal Storage in the CT Scanner in the Mobile Unit The imited internal storage capacity poses a significant challenge. Once the storage reaches its maximum capacity, new exams can be performed, and older exams can be deleted to free up space. This limitation necessitates the regular management of stored data, which includes the timely transfer of completed exams to an external storage system or cloud-based server, ensuring that the CT unit can continue to operate efficiently without interruptions.	**Image Loss and Delays** Internet instability also caused delays in transmitting exams to the server. In some cases, exams that had not yet been uploaded were inadvertently erased from the CT scanner's internal storage, resulting in the permanent loss of images. These exams had to be redone, leading to delays in patient care and additional radiation exposure.

Regular Server Checks: Implement routine checks of patient images on the server to detect errors in patient data, prevent image duplication, and ensure no patient images are missing. This proactive approach will help maintain data integrity and reduce the likelihood of operational errors.

Enhanced Multidisciplinary Communication: Strengthen communication between the technical team and medical professionals. Improved collaboration will help identify and address operational issues quickly, significantly reducing potential errors and ensuring a smoother workflow.

Addressing these critical areas can significantly improve the operational efficiency of the mobile CT unit, ultimately leading to better patient outcomes and more reliable diagnostic processes.

Conclusion

The ProPulmão project, like any pilot initiative, faced unexpected challenges that required adaptive solutions. In instances where issues were not immediately resolved or detected, the project's development benefitted from these challenges by fostering the creation of more efficient work protocols. This process involved holding regular meetings with the development team, training the involved professionals to identify server instabilities quickly, and forming dedicated teams to verify patient data. Additionally, the project improved techniques for the optional storage of patient images to mitigate data loss in case of technical difficulties. In conclusion, the ProPulmão project has provided valuable insights into the epidemiological profile of lung cancer in remote cities of Bahia. The lessons learned from this experience will serve as a solid foundation for future projects with similar objectives, contributing to the scientific community and raising public awareness about the importance of early diagnosis and the dangers posed by lung lesions.

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