Intra-Hospital Transport of Patients on Non-Invasive Ventilation: Review, Analysis, and Key Practical Recommendations by the International NIV Committee

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Cite this article as: Schreiber A, Domínguez Petit AJ, Groff P, Purro A, Ferrari R, Antonelli A, et al. Intra-hospital transport of patients on non-invasive ventilation: review, analysis, and key practical recommendations by the International NIV Committee. Eurasian J Pulmonol 2017; 19: 124-9

Abstract

Intra-hospital transport is often needed for diagnostic and therapeutic procedures that cannot be performed at the bedside. However, moving patients from the safe environment of an Intensive Care Unit (ICU) can lead to a variety of complications and adverse events, the risk is even higher in ventilated patients. This review is intended as a guide on how to prevent and avoid these adverse events during intra-hospital transport of patients on non-invasive ventilation (NIV). Greater attention should be paid to NIV indications and the selection of the patients to be transported. Detailed planning, preparation, and communication between the ward of origin and destination site, appropriate equipment, skilled staff, and continuous monitoring are the key major determinants of success in transporting critically ill patients on NIV. These points are discussed and analyzed in detail.

Keywords: Acute respiratory failure, emergency department, intensive care unit, intra-hospital transport, non-invasive ventilation

INTRODUCTION

Intra-hospital transport of critically ill patients is often necessary for diagnostic and therapeutic procedures that cannot be performed at the existing location or bedside. However, moving patients from the safety of an Intensive Care Unit (ICU) or other high-intensity care units is associated with an overall complication rate of up to 70% (1-3) and a mortality rate of 2% (4). Mechanical ventilation, with its requirement of specific equipment and expertise, might further increase the incidence of transport-related adverse events (5, 6).

Non-invasive mechanical ventilation (NIV) has been proven to be effective in patients with acute respiratory failure (ARF) of various etiologies. Its application in both pre-hospital and in-hospital settings has increased significantly to the detriment of invasive mechanical ventilation, especially in obstructive pulmonary disease (COPD) or selected cases of acute cardiogenic pulmonary edema. Over the years, there has been an increase in the number of neuromuscular patients or "patients at the end of life" asking not to be intubated and to manage their critical respiratory status with NIV. There is also

Received Date: 22.02.2017
Accepted Date: 02.04.2017

DOI: 10.5152/ejp.2017.73745

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• Available online at www.eurasianjpulmonol.com

growing evidence of its efficacy in other conditions such as pulmonary contusion, pneumonia, and near-fatal drowning (7-11). Consequently, intra-hospital transfers of patients on NIV have become an increasingly common occurrence.

Furthermore, past-generation ICU ventilators or intermediate ventilators did not have sufficient autonomy to allow use during transfers due to their limited battery life expectancies or gas supply, while past ventilators dedicated to transport did not provide adequate ventilation modes for NIV. Today, there is a wide range of ventilators offering the opportunity to apply both conventional invasive and non-invasive mechanical ventilation. This means that patients may be transferred to different sections of the hospital without changing the modality and parameters of their ventilatory support. It is notable that while unexpected events during the intra-hospital transfer of critical patients receiving conventional ventilation have been extensively reviewed (4, 12-15), few recommendations regarding patients receiving NIV support are available.

This review is intended as a guide for the seamless intra-hospital transport of patients who, once stabilized, have been successfully put on NIV.

Intra-Hospital Transport and NIV

Intra-hospital transfers of NIV patients are usually made: 1) from the Emergency Department (ED) to the ICU or to another high-intensity ward with experience in handling NIV (e.g., the Respiratory Intermediate Care Unit), 2) between the ED or the ICU and the Radiology Department (Figure 1); 3) between different areas of the latter unit; and 4) between the ED/ICU and specialized care units, such as the endoscopic or hemodynamic unit (16, 17).

Hospital architecture and the location of the areas to be reached significantly affect the time spent performing transfers and the exposure to potential adverse effects. Ideally, once the circuit transfer has been activated, the transport of a patient on NIV to a different hospital section should not exceed 10–15 minutes. However, if the transport is for a diagnostic or therapeutic procedure, such as a computer tomography scan, magnetic resonance imaging, or gastrostomy tube placement, the time spent outside a controlled environment can be between 30 and 90 minutes.

Unlike pre- or inter-hospital transports, which are limited by restrictions related to ambulance transfer, intra-hospital transports are facilitated by the greater availability of resources, equipment, and space.

Prior to the intra-hospital transfer of any critically ill patient, it is crucial to check some key elements and equipment. (Table 1) (18).

NIV Indications and Selection of Patients to be Transported on NIV

Hemodynamic stability, preserved consciousness, and the ability to protect airways are definite requirements for NIV application (19). Partial-responders or non-responders to this technique, or patients in whom the indication of a NIV approach is debatable, are poor candidates for transfer while on NIV. Similarly, patients with poor ventilator synchronization or who are persistently dyspneic despite efforts to optimize their ventilator settings, as well as patients who are agitated and uncooperative or have severe bronchorrhea, need to be further evaluated and stabilized before transfer. Therefore, the balance between indications and contraindications of NIV should be correctly weighed up, and possible adverse events that might occur during transfer associated with either NIV interruption or the transfer of a critical ventilated patient should be taken into account before moving because the clinical situation can abruptly worsen and become life threatening.

Successful intra-hospital transport primarily requires effective communication, appropriate planning, competent staff, and compact, solid equipment, including portable ventilators and a reliable monitoring system (5, 20-26).

Therefore, once the feasibility of moving a patient on NIV from the initial care unit has been assessed, before starting the transfer it is crucial to ensure detailed communication and coordination between the various teams involved in order to avoid delays and limit exposure to adverse events; to select staff adequately trained in NIV, airway management, and cardio-pulmonary resuscitation; and to provide clear instructions and a simple flow-chart (printed or digital) illustrating the role of every member of the transport team.

It is important to define the accompanying equipment (ventilators, manual resuscitator, masks, and monitoring equipment) necessary to carry out the transport and to promote the acquisition of in-depth knowledge of the characteristics and functioning of the devices in use during transport.

Pre-Transport Preparation, Planning, and Staff

Before moving, the goals of transport should be established and appropriate staff and equipment assembled. All patients on NIV should be accompanied by at least one physician, one nurse or respiratory therapist trained in airway management and cardio-pulmonary resuscitation, and one technician (5). Of course, it is of pivotal importance that the personnel involved in the transfer are confident with NIV support ventilators and their modalities, accessories, and interfaces in order to recognize and tackle any problems that might arise. The team receiving the patient must be given advance warning in order to ensure that the destination site is operational and ready to receive the patient.

Communication should be centralized to ensure the optimal use of resources. Before initiating and on arrival at the receiving unit, there should be direct communication between the accompanying team and the receiving party. A form reporting the patient's medical history, on-going treatment, ventilator settings, vital signs, and any major events that have occurred during transport should be filled out (see attached patient-report model for details). We also suggest that a clear clinical flow-chart is made readily accessible to all staff members involved in sending, transferring, and receiving the patient that reflects each member's role in the transfer process.

Accompanying Equipment

Ideally, accompanying equipment should be lightweight, compact, and sturdy in order to be person-portable, maneuverable, and easily transportable through corridors and lifts. In order to minimize problems and unexpected transfer-related events and to facilitate movements of the patient and the devices, it is important to use specific and dedicated equipment, possibly placed on stands with wheels or directly attached

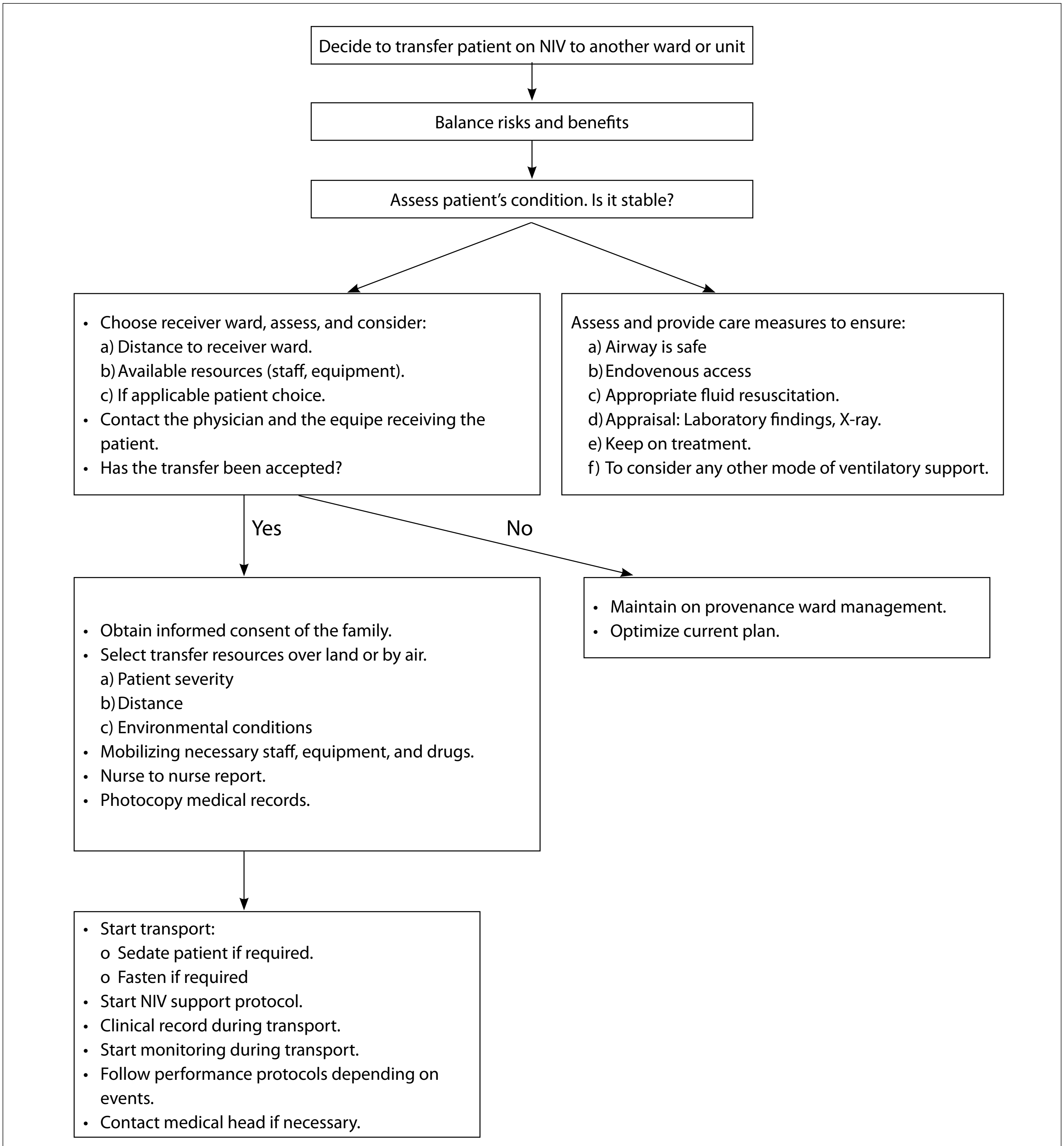

Figure 1. Main key recommendations for intra-hospital transport of patients receiving non-invasive ventilation

to the bed. All equipment should be properly positioned and secured to prevent it from falling off as the patient's bed is moved. There should be a sufficient number of staff members to transport the bed, ventilator, monitoring equipment, and non-suspendible infusions.

Table 2 provides an equipment checklist and practical advice to consult prior to initiating intra-hospital transport of a patient receiving NIV. We consider that the following main key aspects need to be taken into account regarding devices and interfaces.

Ventilators

A wide range of ventilators able to supply NIV is available. Some ventilators commonly used in the ED are specifically designed for non-invasive mechanical support, while others, more typical of ICUs, allow

Table 1. Key elements, equipment and practical checking for intra-hospital transport

1. Ensure proper indication of NIV
2. Assess the risks and benefits of alternatives (high-flow oxygen therapy, invasive VM)
3. Decide if keep to NIV or not
4. Equipment and practical checking:
a. Before starting the transfer, verify availability and correct functioning of intubation, ventilation bag, and proper medication to perform intubation if the patient's respiratory status deteriorates
b. Have a source of oxygen with sufficient volume for the secured transfer
c. Have a portable monitor that provides ECG and heart rate monitoring and that allows for the measurement of arterial pressure
d. Have a pulse oximetry (always) and capnography (desirable)
e. If a CPAP high-flow device is used:
- Check the proper functioning of the manometer (to maintain desired level of CPAP)
- Check suitability of the flowmeter
- Evaluate and adjust the position of the interface and the correct connection of the hose, filter, and oxygen source
f. If a mechanical device for NIV is used:
- Check the battery charge status
- Monitor tidal volume, respiratory rate, level of PEEP, leaks, and the FiO2 system provided
- Set system alarms
- Evaluate the tightness of the interface and the correct connection between different parts
a. -Have appropriate medication (sedatives, opioids, nitrites, etc),resuscitation drugs (atropine, adrenaline, amiodorone, etc), rapid-sequence intubation devices and drugs (intubation tubes, laryngoscope, airway, injector, intravenous cannula, rocuronium, ketamine, midazolam, etc)

Assess the risk/benefit ratio of an intra-hospital transport. Consider the proper indications (and contraindications) of NIV. Assess the risks and benefits of NIV alternatives (standard oxygen therapy, high-flow oxygen therapy, invasive MV). Properly select patients to be transported on NIV and weigh the potential risks and benefits of moving a patient with ARF on NIV. Evaluate the availability of transport equipment, monitoring, and staff. Predict and be prepared to deal with possible adverse events and complications that might occur during transport.

both invasive and non-invasive ventilation. Both intermediate ventilators dedicated to NIV and ICU ventilators with an NIV algorithm may be used for transport according to the patient's clinical features, previous ventilator modality, and fraction of inspired oxygen needed.

While the vast majority of NIV-dedicated ventilators can travel both on wheels or attached to the bed, some ICU ventilators with the NIV algorithm need to be transported on a dedicated wheeled support. In the event that the duration of the transport is extended, an essential consideration is the provision of an adequate battery and oxygen supply.

Therefore, before moving the patient, it is critical to check the status of the battery and oxygen cylinders and to carry electrical connections, adapters, and extensions to connect oxygen and other important devices to wall jacks and joints.

Table 2. Major complications and contraindications during intra-hospital transport

Major complications:	
1.	The loss of PEEP/CPAP can lead to hypoxemia
2.	The changes in the patient's position might involve hypotension and hypoxemia
3.	Arrhythmias associated with transporting the critically ill
4.	Malfunction of the equipment used, which can result in loss of patient monitoring or in the collection of incorrect values
5.	The movement can cause the disconnection of ventilatory support and compromise the patient's respiratory function
6.	The movement can cause the accidental withdrawal of catheters and interruption of intravenous medications the patient is receiving
Major contraindications for transferring patients on NIV:	
1.	Inability to provide adequate oxygenation and ventilation during transport
2.	Inability to maintain adequate hemodynamics during transport (hemodynamic instability, shock, unstable ischemic heart disease, poorly controlled arrhythmias?)
3.	Inability to monitor the patient's cardiopulmonary status during transfer
4.	Inability to maintain control of the airway during transport (respiratory arrest, upper gastrointestinal bleeding, excessive secretions, airway obstruction, increased risk of pulmonary aspiration, severe encephalopathy with GCS <10 points, burns, traumas, or facial surgery
5.	Shortage of staff to perform the transfer under optimal conditions
6.	Insufficient knowledge on the transfer of critically ill patients among the staff members
7.	Lack of communication and coordination between the various departments involved

Generally, transport ventilators dedicated to NIV have an internal battery life of 5 hours or longer, while ICU ventilators are equipped with shorter-life replaceable batteries. We strongly recommend that the operators involved in the transfer have an in-depth knowledge of the functions and settings of the ventilator in use. This seems particularly true for alarm settings (especially disconnection, low tidal volume, low oxygen pressure, and low battery alarms) that should be calibrated to real clinical and operational necessities, avoiding unnecessary ambient noise.

Furthermore, it is crucial to be aware of the potential danger of working with different ventilators or breathing circuits or of changing them for the transfer because of the risk of incorrectly matching breathing circuits (with a passive exhalation port or with an active exhalation valve) with the wrong interface. We therefore recommend clearly labeling circuits as "use only with vented masks" or "use only with non-vented masks."

Table 3. Monitoring during intra-hospital transport

1.	Continuous ECG tracing
2.	Non-invasive intermittent blood pressure measurement (NIBP)
3.	Continuous oxygen saturation (SaO2) measurement
4.	Respiratory rate (RR) and tidal volume (VT) evaluation
5.	Pressure and flow curve observation to assess patient-ventilator synchrony and air leaks (if available in the ventilator in use)
6.	Continuous clinical surveillance throughout the entire duration of the transfer (inspection, auscultation, and assessment of the level of consciousness)

Manual ventilation with a manual resuscitator should always be available in the event the ventilator suffers a mechanical failure, and at any time during the transport it should be possible to switch immediately from mechanical ventilation to manual ventilation through a mask or, if necessary, an endotracheal tube.

Interfaces and Circuits

To date, a variety of different types of interfaces have been validated for NIV, but facial (full-face or oro-nasal) masks and helmets are the most widely used in the acute setting (16-19). While ventilator modalities are set to a specific clinical goal, the choice of interface affects the prevention of leaks and patient comfort, both of which are closely related to the success of the technique (20-24). Therefore, in the absence of specific recommendations in this setting, it seems logical that a patient who is well adapted to a particular interface should continue with the same interface during the transport. This practice is also convenient in terms of hospital costs. In any case, this policy must be matched with features and configurations of the ventilator system adopted for the transport. Considering that the simplest ventilator circuit should generally be given precedence for transport (25), if the patient is shifted from a dual-limb to a single-limb circuit, as previously mentioned, there might be the need to switch from a non-vented to a vented mask or to insert a proper exhalation valve (18, 26, 27). In this regard, it is important to consider that some single-limb circuit ventilators are tested to work with their specific brand of masks in order to guarantee full CO_2 rebreathing prevention. Furthermore, it is essential to ensure a proper fit of the mask before the transfer and to check it throughout the process because accidental displacements and air leaks frequently occur in this setting.

Ventilator Setting

Although a discussion of ventilator modalities goes beyond the intent of this paper, during transport it is important to maintain the patient on the same parameters to which he or she is well adapted. This might require a correction of the settings when switching a patient from an "above PEEP algorithm" ventilator to an "under PEEP algorithm" in order to maintain the same level of ventilatory support. For this and the aforementioned reasons, as a general rule it is preferable to avoid replacing one NIV system with another because this might result in the loss of the benefit obtained. However, this can be difficult because patients are generally transported with specifically dedicated devices, and different wards in the hospital might adopt different ventilators (27-30).

In non-emergency situations, information on how the ventilator algorithm works is easily obtainable. In emergency situations, however, when the patient is unstable, there might not be enough time to get this information. To overcome this problem and to avoid potential errors, a proposal could be to clearly label ventilators as "EPAP+IPAP algorithm" or "PS+PEEP algorithm." This might be particularly useful in large hospitals where a wide variety of ventilators are used.

If ventilator substitution is unavoidable, we also recommend connecting the patient to the transport ventilator 5–10 minutes before leaving the ward of origin and verifying the adequacy of patient tolerance and stability (25). When substituting the ventilator and circuit, it is advisable to disconnect the heated humidification system and to connect a heat and moisture exchanger (HME) to ensure adequate humidification of the patient's airways and to protect the ventilator.

Finally, although complete stabilization of the patient must precede the decision to transfer, one must be prepared for the possibility of an abrupt worsening of the patient's clinical condition during transport. Therefore, adequate instrumentation and medications for advanced airway control and cardio-pulmonary resuscitation must be part of the equipment for intra-hospital transport (25-29).

Monitoring

Patient monitoring during transfers should address the main potential complications as listed in Table 2.

These complications include disconnection of ventilatory support or CPAP or a change in the ventilatory pattern with consequent worsening of hypoxemia or hypercapnia, changes in the patient's position with the risk of aspiration, disconnection or malfunctioning of the monitoring system itself, arrhythmias secondary to hypoxia or acid-base imbalance, accidental withdrawal of venous lines with interruption of the administration of current medications with the potential occurrence of hypotension, and other complications (29-32).

If the patient to be transferred requires close blood gas monitoring, an arterial sample should be taken and analyzed before starting the process. During transport, the ventilatory pattern (including respiratory rate, oxygen saturation, and patient-ventilator synchrony), patient dyspnea, and comfort should be monitored. These aspects are summarized in Table 3.

After the transport, it is equally important to review any problems encountered during transfer in order to avoid repetition in the future, and there should be the production of records and audits and periodical staff re-training programs on NIV and transport procedures and potential adverse events. Figure 1 summarizes the key practical recommendations for a safe intra-hospital transport of patients receiving NIV.

Key Recommendations

Intra-hospital transport can lead to a variety of complications and adverse events that might expose the ventilated patient to risks, including death. Greater attention should, therefore, be paid to whom we transport, where, when, and how. Appropriate communication, planning, staff, equipment, and monitoring are key to the successful transport of patients on NIV. Safe transport is best considered when transferring the unit with the patient instead of transferring the patient away from the unit. Every effort should be made to maintain the pre-existing setting, but, at the same time, to take only the essential devices. A critical review of the problems and adverse events occurring during previous transfers and periodical staff re-training programs are essential to improving outcomes (33, 34).

Peer-review: This manuscript was prepared by the invitation of the Editorial Board and its scientific evaluation was carried out by the Editorial Board.

Author Contributions: Concept - A.M.E., A.S., A.J.D.P., P.G., A.P., R.F., A.A., S.S., R.C., G.K., P.B.D., G.F., L.D.; Design - A.M.E., A.S., A.J.D.P., P.G., A.P., R.F., A.A., S.S., R.C., G.K., P.B.D., G.F., L.D.; Supervision - A.E.; Resources - A.M.E., A.S., A.J.D.P., P.G., A.P., R.F., A.A., S.S., R.C., G.K., P.B.D., G.F., L.D.; Materials - A.M.E., A.S., A.J.D.P., P.G., A.P., R.F., A.A., S.S., R.C., G.K., P.B.D., G.F., L.D.; Literature Search - A.M.E., A.S., A.J.D.P., P.G., A.P., R.F., A.A., S.S., R.C., G.K., P.B.D., G.F., L.D.; Writing Manuscript - A.M.E., A.S., A.J.D.P., P.G., A.P., R.F., A.A., S.S., R.C., G.K., P.B.D., G.F., L.D.;Critical Review - A.E.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

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