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Intrapulmonary Percussive Wntilation as a Lung Recruitment Strategy in Brain Dead Organ Donors

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INTRAPULMONARY PERCUSSIVE VENTILATION AS A LUNG RECRUITMENT STRATEGY IN BRAIN DEAD ORGAN DONORS

by

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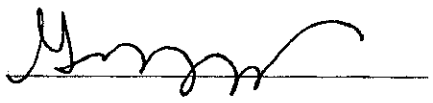
Signature 

Date 3/16/16

Abstract

Objective: To determine the strength of the evidence evaluating the effectiveness of IPV as a safe alternative or adjunctive therapy to traditional CPT among potential organ donors.

Data Sources: Literature search conducted February 2015-November 2015 using PubMed, CINAHL, Scopus, and bibliographies of pertinent articles. Search terms: *intrapulmonary percussive ventilation, chest physiotherapy, chest wall oscillation, organ donors, and ventilation.*

Study Selection: Articles in English from 1994 to present directly compared IPV to CPT or conventional (no) therapy.

Data Extraction: AACN Levels of Evidence was used to determine the strength of evidence. Level B and Level C articles were used.

Data Synthesis: No studies were found utilizing IPV in the donor population. Results from studies utilizing IPV in other populations indicated IPV had no adverse effects, improved sputum clearance, oxygenation, and reduced atelectasis and pneumonia in patients with artificial airways.

Conclusions: IPV may be a safe, and effective alternative or adjunctive CPT therapy and improve the number of lungs available for transplantation. Clinical research is essential to determine the effectiveness of this therapy for lung recruitment in the donor population.

Key Words: *chest physiotherapy, intrapulmonary percussive ventilation, lung recruitment, organ donor, ventilation*

Introduction

Lung transplantation is a common treatment for patients with end-stage lung disease. In 2013 a record 2,394 candidates were listed for lung transplant. The same year, a record 1,946 lung transplants were performed.[1] Presently, the supply of viable lungs for transplant does not meet the demand. In 2013, 448 listed patients did not receive a lung transplant, and 175 patients died while waiting.[1,2] Clearly, the number of potential organ donors is insufficient to meet the demands of the growing waitlist. For this reason, every opportunity for successful organ donation should be maximized.

Arterial oxygenation levels greater than 300 mmHg, has been shown to increase the number of organs transplanted per donor.[1] One strategy to increase arterial oxygenation levels and maximize donation potential is lung recruitment.[2] This essential goal is complicated because physiologic changes common in organ donors can affect lung quality. During brain stem herniation, the sympathetic nervous system is activated. A massive release of catecholamines can cause increased pulmonary capillary pressure and permeability. When this occurs, neurogenic pulmonary edema may develop and further complicate oxygenation.[3] After brain death, donors do not have the respiratory drive or cough reflex required to clear secretions. The result is the accumulation of secretions in the airways, impaired gas exchange, and difficulty in the optimization of lungs for transplant.[4] In addition, brain dead organ donors are ventilated through artificial airways, such as an endotracheal tube. The presence of an endotracheal tube impairs secretion movement and mobility, which can lead to airway obstruction, atelectasis, or pneumonia.[5] These conditions might be hastened when prior to brain death, lung therapies that could be utilized to overcome challenges to secretion clearance are contraindicated due to increased intracranial pressure (ICP). Strategies such as chest physiotherapy (CPT), dependent

positioning, frequent rotation, and alveolar recruitment can cause excessive stimulation and may be avoided when ICP is elevated.[3] The next section will describe the evidence related to methods for lung recruitment.

Lung Recruitment

Lung recruitment is a term used in the transplant community to designate a group of interventions employed to mediate and reverse the effects of impaired secretion clearance, inflammation, and atelectasis. Lung recruitment has been shown to increase lung transplantation rates.[2] Such strategies include alveolar recruitment, prone positioning, routine albuterol administration, ventilator associated pneumonia prevention and chest physiotherapy with postural drainage (CPT).[2] Chest physiotherapy and alternatives will be the focus of this literature review.

Chest physiotherapy involves using manual or assistive devices, such as a hand-held percussor, vest, or bed, to loosen secretions in the airways. Chest physiotherapy alone does not mobilize secretions to the trachea for removal. Postural drainage is often used in combination with CPT to promote the movement of secretions to the main airways where they can be suctioned.[6] While CPT is an accepted modality for secretion management for potential organ donors, newer modalities may be effective in combination with, or instead of CPT.[2,6]

Intrapulmonary Percussive Ventilation

Intrapulmonary Percussive Ventilation (IPV) is a relatively new modality for secretion clearance. During IPV, vibrations are delivered directly to the airways, instead of applying high frequency vibrations to the chest wall, as in CPT. Vibrations are delivered at a rate of 60 to 400 cycles/min to loosen and move secretions to the main airway for removal via cough, or

suctioing.[7] The effectiveness of IPV has been studied in patients with chronic diseases such as cystic fibrosis, neuromuscular disease and chronic obstructive pulmonary disease (COPD).[8] This literature review aimed to discover evidence that would support or reject IPV as a safe and potentially more effective modality than CPT for secretion clearance, in the effort to maximize the viability of lungs for transplant.

Methods

Literature Search

A systematic literature review was conducted in two phases. The first phase utilized MEDLINE (via PubMed) and the Cumulative Index of Nursing and Allied Health Literature (CINAHL) databases. Terms included were intrapulmonary percussive ventilation, chest physiotherapy, chest wall oscillation, organ donors, and ventilation. The initial search yielded 19 articles. The second search phase involved a repeat search of PubMed and CNAHL as well as a Scopus search, which yielded an additional article. Additionally, reference lists of discovered articles were reviewed for additional studies throughout the literature search process.

Inclusion and Exclusion Criteria

Articles were limited to those published from 1994 to present. Studies that directly compared IPV to CPT or conventional (no) therapy were chosen. Literature review articles and those not available in English were excluded. Eleven articles met inclusion criteria, four of which involved patients with artificial airways. No studies were found that examined the use of IPV in the potential donor population.

Examination of Quality of Evidence

The Association of Critical Care Nurses (AACN) Levels of Evidence was used to grade the quality of the evidence.[9] Table I outlines the AACN Levels of Evidence. Nine articles met Level B criteria and three met level C criteria. Eleven of the twelve articles were single-center studies with samples sizes ranging from 4 to 44 patients. The remaining study involved two centers. Specific details of study design, sample size and level of evidence for each article can be obtained from Appendix I.

Table I: AACN Levels of Evidence

Level	Description
Level A	Meta-anaylsis of multiple controlled studies or meta-synthesis of qualitative studies
Level B	Well designed control studies, both randomized and non-randomized
Level C	Qualitative studies, descriptive or correlational studies, integrative reviews, systematic reviews, or randomized control trials with inconsistent results
Level D	Peer-reviewed professional organizational standards, with clinical studies to support recommendations
Level E	Theory-based evidence from expert opinion or multiple case reports
Level M	Manufacturer's recommendations only

Adapted from Armola et al[9]

Results

Oxygenation is a complex process. Sputum in the airways can directly impact oxygenation by restricting or limiting airflow to the alveoli where gas exchange occurs. The exchange of gases at the cellular level in the alveoli (oxygenation, carbon dioxide clearance, and regulation of arterial blood pH) is the result of optimal lung function.[3] Studies included in this review employed a variety of measures to identify the effectiveness of IPV. Variables measured include sputum weight, oxygenation and gas exchange, and lung function parameters.

Additionally, studies measured the consequences of the failure of essential lung function i.e. pneumonia and atelectasis. Adverse event occurrence is an important consideration when examining the safety of a treatment and was considered in all twelve studies. The evidence will be reviewed according to the variables measured by researchers.

Sputum Weight

The purpose of CPT and IPV is to increase secretion clearance to optimize gas exchange and decrease risk of infection.[10] Sputum weight may be considered an effective method to estimate the efficacy of CPT and IPV. However, sputum weight can be influenced by factors such as saliva, and the ability to clear secretions (cough).[7]

Four studies utilized sputum weight as an outcome measure.[7,10–12] Three level B randomized crossover studies were found IPV did not significantly increase sputum weight after treatment. Patients in these studies included those with a diagnosis of cystic fibrosis and bronchiectasis, without artificial airways and with intact cough reflexes.[10–12] Yet , in a lower level case series study, sputum weight was significantly higher in patients with Duchenne's muscular dystrophy when retrieved directly from the trachea after combined CPT and IPV treatment.[7] While contrary to the other study findings, sputum weight from this population is considered more accurate because these patients had tracheostomies allowing for removal of secretions from the trachea. Direct removal of secretions in this manner prevented oral secretions from mixing with the sputum and confounding results.[7]

While sputum weight can be used to measure the amount of secretions removed from the airway, it is unclear if that weight directly correlates to improved lung function. There is limited

evidence that sputum clearance in itself is a good measure of improved lung function and morbidity.[12] Other measurements, such as gas exchange and oxygenation may be more telling.

Gas Exchange and Oxygenation

While studies examining the effect of IPV and CPT on sputum clearance were utilized to evaluate the effectiveness of IPV, direct evidence of improved gas exchange and oxygenation may more directly measure the usefulness of IPV in the potential donor population. Parameters such as pH, PaCO2, PaO2 and P/F ratio are used in the organ donor population to assess lung function and viability for transplant.[1,2] Seven studies (four level B and three level C) utilized oxygenation measurements to examine the effectiveness of IPV in patients with tracheostomies, COPD, spinal cord injury or cystic fibrosis.[11,13–18] The oxygen index significantly improved in three randomized control studies after IPV, or combined IPV and CPT treatments.[13,14,16] One of two lower level studies also found a significantly higher PaO_2 after IPV therapy.[15,17] Pulse oximetry can also estimate arterial oxygenation via a non-invasive probe, but is less accurate than direct arterial measurement of PaO_2[3]. Testa et al found oxygen levels measured by pulse oximetry increased in patients that received IPV with CPT, but did not significantly improve in Paneroni et al's randomized cross-over study.[11,16] Carbon dioxide clearance, measured by $PaCO_2$ levels, was improved in one level B and one level C study.[13,17] A low level retrospective review without statistical analysis noted decreased oxygenation delivery requirements after a treatment bundle including IPV.[18] Overall, oxygenation measurements and gas exchange seemed to improve with IPV alone or with combination IPV and CPT therapy.[13,14,16–18]

Pneumonia and Atelectasis

Pneumonia and atelectasis are known to impair gas exchange and lung function.[5,13] Prevention and treatment of both conditions is considered in the care of potential organ donors.[2] Three level B randomized control studies examined pneumonia or atelectasis.[5,13,14] Two studies measured pneumonia rates in patients with tracheostomies or COPD.[13,14] While Antonaglia and associates did not find a significant decrease in pneumonia rates in their patients with COPD who received IPV, Clni et al found lower rates of pneumonia in their patients with tracheostomies when IPV was added to CPT.[13,14] Ventilated pediatric patients with evidence of atelectasis via chest x-ray had significant improvement in atelectasis after IPV as determined by blinded scorers.[5] This evidence suggested that IPV may lower the incidence of pneumonia in patients with tracheostomies and decrease atelectasis in children. Thus IPV may reduce atelectasis and pneumonia in the donor population.[5,13]

Lung Function Measurements

Various lung function measurements have been utilized to study the effectiveness of IPV. Six of the studies in this review employed lung function measurements to help determine how CPT and IPV affect lung function.[5,14–17,19] The positive effects of IPV on lung function measurements include increased maximal expiratory pressures after IPV, or when combined with CPT.[14,16] Also, expiratory flow limitation and airway occlusion pressure were decreased from baseline measurements following IPV therapy in patients with COPD.[17] Conversely, IPV treatment did not significantly improve forced expiratory flow, forced vital capacity, mid-expiratory flow, static compliance, inspiratory muscle strength or expiratory muscle strength.[5,15,19] With this in mind, it is unclear if any pulmonary function tests would be appropriate variables to determine the effectiveness of IPV in potential organ donors. The lack

of responsiveness in an organ donor would preclude the delivery of some pulmonary function tests.

Adverse Events

In all the studies reviewed, 163 patients received IPV in total. Of these patients, only one experienced an adverse reaction.[5,10–14,16–19] Homnick et al described one patient who developed hemoptysis attributed to P. aeruginosa pneumonia during IPV. After resolution of the pneumonia, IPV was restarted with no further ill effect.[19]

Discussion

Evidence indicates that IPV is a safe and effective modality for the management of secretions in various patient populations, including those with cystic fibrosis, COPD, atelectasis, and neuromuscular disease. IPV, alone or in combination with CPT is at least as effective as CPT alone.[5,7,10,12–14,16,19] Five studies found IPV correlated with improved outcomes.[5,7,13,14,16]

Patients with artificial airways have impaired mucocilliary clearance due to sedation, positioning, immobility, impaired cough, and inadequate humidification of inhaled air.[20] Brain dead organ donors are at greater risk for impaired oxygenation due to mucocilliary clearance dysfunction because they lack a cough and respiratory drive. For this reason, studies that included patients with artificial airways were compared in order to determine how IPV therapy improves lung function in a population that more closely matches our population of interest. IPV with or without CPT correlated with greater secretion clearance, improved gas exchange, oxygenation, maximal expiratory pressures, and decreased atelectasis and pneumonia in three level B studies.[5,7,14] Toussaint and colleagues' study is of particular interest because their population with Duchenne muscular dystrophy had impaired or no ability to cough, similar to the

brain dead population. The researchers were able to remove and measure sputum directly from the main airway. IPV was more effective than CPT at moving secretions to the main airways and for direct removal from the trachea, limiting confounding factors.[7] These findings are important to the purpose of this evidence search because of the donor patient's inability to assist with airway clearance.

Antonaglia et al and Clini et al measured P/F ratio to determine the effectiveness of IPV therapy. Both groups found that IPV exerted a statistically significant positive effect on P/F ratio.[13] In the organ donor population, P/F ratio is the value most used to assess and evaluate the effectiveness of lung recruitment strategies and the suitability of lungs for transplant.[1,2]

The potential benefits of employing IPV to donor patients may outweigh the resources required for the intervention. For example, although IPV requires training and adjustment in setting parameters to determine the most effective delivery for the patient, it is less likely to have varied effects from provider to provider.[10] Chest physiotherapy requires the provider to position the patient correctly and apply percussion to all lung fields. It has been hypothesized that the rapid changes in airflow during IPV cause a cough-like force.[14] Therefore, IPV may not require postural drainage to be effective at moving the secretions to the main airways. Quality research is essential to determine the importance of postural drainage during IPV therapy.

Future research will need to determine outcome variables appropriate for examining the effectiveness of IPV and CPT relevant to brain dead organ donors. The studies in this systematic review that used sputum weight as a measure of the effectiveness of lung physiotherapy conceded this measure may not be the most effective variable to determine long-term improvement in lung function.[12,13,18] Oxygenation index (P/F ratio) is used to determine viability of lungs for transplant and is routinely obtained in the care of all brain dead organ donors.[1,2]

Therefore, P/F ratio may be a good measure of improved oxygenation. The end goal of pulmonary recruitment, including CPT, is an increase in the number of organs transplanted per donor, specifically lungs. Organs transplanted per donor, rate of entrance to OR with the intention to transplant and actual transplant rates are outcomes most important to measure in order to determine the benefit of IPV for potential organ donors.[2,3,6,21]

Conclusion

IPV has not been studied in the brain dead organ donor population. While the studies in patients with cystic fibrosis, COPD, atelectasis, and neuromuscular disease indicate that IPV is safe and as effective as CPT, more research is needed to determine the utility of this method for lung recruitment in potential donors. The data associated with the use of IPV for patients with artificial airways, especially those with impaired cough, appears promising that IPV may also be an effective modality for brain dead organ donors. Future research in to the use of IPV in the brain dead donor population should include outcomes directly linked to donation assessment and evaluation, such as P/F ratio and lung recovery and transplantation rates.

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Appendix I

Literature Review Table					
Citation	**AACN Level**	**Design**	**Sample**	**Variables**	**Findings**
Antonaglia et al, 2006[13]	Level B	RCT CPT vs. IPV	40 acute COPD exacerbation	pH, PaCo2, P/F ratio, RR, HR, ICU LOS, metabolic complications; sepsis, pneumonia, and intubation rates	Improved PaCO2 and P/F; shorter ICU stay; lower intubation rates
Clini et al, 2006[14]*	Level B	RCT CPT vs. IPV with CPT	44 with tracheostomies 21 control; 23 experimental	ABG; P/F ratio; maximal expiratory pressure (MEP); pneumonia rates	Experimental group has improved P/F ratios, MEPs and lower rates of pneumonia
Deakins & Chatburn, 2002[5]*	Level B	RCT CPT vs. IPV	12 pediatric with atelectasis 7 control; 5 experimental	Atelectasis scores and static compliance	Experimental group had improvement in atelectasis
Homnick, White, & de Castro, 1995[19]	Level B	RCT CPT vs. IPV	16 cystic fibrosis 8 control; 8 experimental	Forced expiratory flow, forced vital capacity, mid-expiratory flow rate every month for 5 months	No difference between control and experimental group
Ides et al, 2012[15]	Level C	Descriptive Study IPV	5 acute COPD exacerbation	Lung function measurements, inspiratory & expiratory muscle strength, diffusion capacity, ABG, Chest CT, dyspnea score	Changes in airway geometry seen. No significant improvement in other measures before and after treatment
Natale, Pfeifle, & Homnick, 1994[10]	Level B	RCT-crossover	9 cystic fibrosis	Sputum weight (wet & dry), pulmonary function	No statistical difference between treatments
Paneroni et al, 2011[11]	Level B	RCT-crossover	22 bronchiectasis	Sputum weight, SpO_2, RR dyspnea	No statistical difference for sputum weight or SpO_2; Decreased RR & dyspnea score
Testa et al, 2014[16]	Level B	RCT CPT vs. IPV with CPT	20 with COPD 10 control/10 experimental	Maximum inspiratory and expiratory pressures, SpO2, HR, RR, BP, dyspnea, ABG	Experimental group had improved maximum inspiratory and expiratory pressures, PaO2, and SpO2

Toussaint, et al 2003[7]*	Level B	RCT-crossover	8 trachostomized with Duchenne's MD	Sputum weight	Increased sputum clearance
Varekojis et al, 2003	Level B	RCT-crossover	24 cystic fibrosis	Wet and dry sputum weight	IPV yielded higher wet sputum weight. No difference in dry weights
Vargas et al, 2009[17]	Level C	Descriptive Study Before and after IPV treatment	25 COPD	PaCO2, PaO2, pH, expiratory flow limitation (EFL), airway occlusion pressure (AOP)	Improved gas exchange, EFL and AOP
Wong, Shem, & Crew, 2012[18]*	Level C	Descriptive Study Before and after treatment bundle including IPV	4 spinal cord injury	FiO2 requirements, PSP level, PEEP	No statistical analysis. Decreased oxygen requirements and lower PSP level after treatment bundle
*denotes study includes patients with artificial airways					

Intrapulmonary Percussive Ventilation and Lung Donation

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Problem:

- There is a great disparity between the number of donor organs available and the ever growing waiting list for life-saving transplants
- Strategies to increase lung function (lung recruitment can increase the number of lungs available for transplant
- Chest physiotherapy (CPT) is the standard intervention for removing secretions during lung recruitment. CPT mobilizes secretions into the smaller airways; though, a cough is necessary to move them into the main airways for clearance
- A lack of cough in brain dead donors limits the effectiveness of CPT. When secretions are not cleared, oxygenation is decreased and infection may develop
- Intrapulmonary percussive ventilation (IPV) is a new modality that mobilizes secretions and actively moves them to the main airway and endotracheal tube for clearance. However, the effectiveness of IPV has not been well studied in the donor population

Purpose:

- Conduct an evidence-based literature review
- Determine the strength of the evidence and evaluate the effectiveness of IPV as a safe alternative to traditional CPT among potential organ donors

Search Strategy:

- Literature search: PubMed MeSH and CINAHL databases
- Key search terms: chest physiotherapy, intrapulmonary percussive ventilation, IPV, percussive ventilation, organ donor, and donor
- Inclusion criteria:
  - Peer reviewed articles comparing or describing IPV to other secretion management modalities
  - From 1994 to current
- Exclusion criteria:
  - Literature review articles
  - Articles not available in English

Literature Review Table

Citation	AACN Level	Design	Sample	Variables	Findings
Antonaglia et al., 2006[1]	Level B	RCT CPT vs. IPV	40 acute COPD exacerbation	pH, PaCO2, P/F ratio, RR, HR, ICU LOS, metabolic complications, sepsis, pneumonia, and intubation rates	Improved PaCO2 and P/F, shorter ICU stay, lower intubation rates
Clini et al., 2004[10]*	Level B	RCT CPT vs. IPV with CPT	44 with tracheostomies 21 control, 23 experimental	ABG, P/F ratio, maximal expiratory pressure (MEP), pneumonia rates	Experimental group has improved P/F ratio, MEPs and lower rates of pneumonia
Deakins & Chatburn, 2002[11]*	Level B	RCT CPT vs. IPV	12 pediatric with atelectasis 7 control, 5 experimental	Atelectasis scores and static compliance	Experimental group had improvement in atelectasis
Hamnick, White, & de Castro, 1995[3]	Level B	RCT CPT vs. IPV	16 cystic fibrosis 8 control, 8 experimental	Forced expiratory flow, forced vital capacity, mid-expiratory flow rate every month for 5 months	No difference between control and experimental group
Ides et al., 2012[5]	Level C	Descriptive Study IPV	5 acute COPD exacerbation	Lung function measurements, inspiratory & expiratory muscle strength, diffusion capacity, ABG, Chest CT, dyspnea score	Changes in airway geometry seen. No significant improvement in other measures before and after treatment
Natale, Pfeiffer, & Hamnick, 1994[4]	Level B	RCT-crossover	7 cystic fibrosis	Sputum weight (wet & dry), pulmonary function	No statistical difference between treatments
Ponerant et al., 2011[7]	Level B	RCT-crossover	22 bronchiectasis	Sputum weight, SpO2, RR dyspnea	No statistical difference for sputum weight or SpO2. Decreased RR & dyspnea score
Testa et al., 2014[6]	Level B	RCT CPT vs. IPV with CPT	20 COPD 10 control/10 experimental	Maximum inspiratory and expiratory pressures, SpO2, RR, HR, BP, dyspnea, ABG	Experimental group had improved maximum inspiratory and expiratory pressures, PaO2, & SpO2
Toussaint, DeWin, Steens, & Soudon, 2003[12]*	Level B	RCT-crossover	8 tracheostomized with Duchenne's MD	Sputum weight	Increased sputum clearance
Varekojis et al., 2003[13]	Level B	RCT-crossover	24 cystic fibrosis	Wet and dry sputum weight	IPV yielded higher wet sputum weight. No difference in dry weight
Vargas et al., 2009[14]	Level C	Before and after IPV treatment	25 COPD	PaCO2, PaO2, pH, expiratory flow limitation (EFL), airway occlusion pressure (AOP)	Improved gas exchange, EFL and AOP
Wong, Shem, & Crew, 2012[15]*	Level C	Before and after treatment bundle including IPV	4 spinal cord injury	FiO2 requirements, PSP level, PEEP	No statistical analysis. Decreased oxygen requirements and lower PSP level after treatment bundle

*denotes study includes patients with artificial airways

Search Results:

- Twelve articles met search criteria
- Studies reviewed in detail and classified by the American Academy of Critical Care Nurses Levels of Evidence
  - Level B: Nine articles
  - Level C: Three articles

Synthesis of Evidence:

IPV was compared to CPT in a variety of ways:

- **Sputum clearance:**
  - Three studies found no significant difference in sputum weights[6,7,9]
  - One study found significantly more sputum clearance in patients who received IPV with CPT when secretions were removed directly from the trachea[10]
- **Gas Exchange and Oxygenation:**
  - Five of seven studies found an improvement in gas exchange and oxygenation in the treatment groups[1,2,8,11,12]
  - Two studies did not find a significant improvement (after one treatment)[5,7]
- **Pneumonia and Atelectasis**
  - One of two studies showed a decline in pneumonia rates[1,2]
  - One study found a significant decline in atelectasis[3]
- **Lung Function:**
  - Results of various lung function tests were not consistent between studies
  - It is unclear how these tests would relate to lung transplant rates
- **Adverse Effects:** 1 of 163 patients who received IPV had an adverse affect (hemoptysis r/t P. aeruginosa infection)[6]
- **Other:**
  - One study found shorter length of stay and time of intubation with IPV[1]
  - CT evidence showed a change in airway geometry after IPV representing secretion clearance in distal airways[5]

Implications for Practice:

- IPV may be a safe and effective alternative or adjunctive CPT therapy
- IPV's ability to improve oxygenation may lead to an increase in available lungs for transplant
- Clinical research is essential to determine the effectiveness of this therapy for lung recruitment in the donor population

Poster presented at Midwest Nurses Research Society – March 17-20, 2016 Milwaukee, Wisconsin

Appendix III

Geralyn Lerg
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Gift of LIfe
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April 24, 2016

Dear Ms. Ohler,

We wish to submit an original literature review article entitled "Intrapulmonary Percussive Ventilation as a Lung Recruitment Strategy in Brain Dead Organ Donors" for consideration by *Progress in Transplantation*. In this paper, we report the strength of the evidence comparing intrapulmonary percussive ventilation (IPV) to chest physiotherapy (CPT) for maintenance of lung function. The evidence indicated that IPV is effective as and perhaps, more effective than CPT. This is significant because every opportunity to improve lungs for transplant should be optimized. Secretion management is a large part of lung recruitment, and IPV is another modality available to move secretions in to the main airways for removal.

We believe that this manuscript is appropriate for publication by *Progress in Transplantation* because it presents evidence to support the medical innovation, IPV, which may increase lungs available for transplant and improve the quality of life for lung recipients. This systematic literature review illustrates how IPV compares to CPT in many patient populations. However, there currently are no published studies in the donor population. We hope that this literature review will spark dialogue, and thought around the study and use of IPV in potential lung donors.

We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

We have no conflicts of interest to disclose. No funding was received for this work.

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Thank you for your consideration of this manuscript.

Sincerely,

Geralyn Lerg