Non-Pharmacological Prevention of Ventilator Associated Pneumonia

Luis Aurelio Díaz, a Mireia Llauradó, b Jordi Rello, b,c and Marcos I. Restrepo d,*

a Geisinger Health System, Danville, Pennsylvania, United States
b CIBER de Enfermedades Respiratorias (CibeRes), Hospital Universitario Joan XXIII, Tarragona, Spain
# Instituto d’Investigació Sanitària Pere Virgili (IISPV), Universitat Rovira i Virgili, Tarragona, Spain
d VERDICT, South Texas Veterans Health Care System Audie L. Murphy Division, University of Texas Health Science Center at San Antonio, Division of Pulmonary and Critical Care Medicine, San Antonio, Texas, USA

ABSTRACT
Ventilator-associated pneumonia (VAP) is the first cause of mortality due to nosocomial infections in the intensive care unit. Its incidence ranges from 9% to 67% of patients on mechanical ventilation. Risk factors are multiple and are associated with prolonged stays in hospital and intensive care units. Additional costs for each episode of VAP range from €9,000 to €31,000.

Thus, its prevention should be considered as a priority. This prevention could decrease associated morbidity, mortality, costs, and increase patient safety.

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Prevención no farmacológica de la neumonía asociada a ventilación mecánica

La neumonía asociada a ventilación mecánica es la primera causa de mortalidad por infecciones nosocomiales en la unidad de cuidados intensivos. Su incidencia oscila entre el 9 y el 67% de los pacientes que requieren ventilación mecánica. Hay múltiples factores de riesgo asociados y aumenta significativamente la estancia en la unidad de cuidados intensivos y en el hospital. El coste adicional por cada neumonía asociada a ventilación mecánica oscila entre 9,000 y 31,000 €.

Por tanto, su prevención debe considerarse una prioridad. Ésta podría disminuir tanto la morbimortalidad asociada como el coste de la atención, y mejorar la seguridad del paciente.

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Introduction

Ventilator-associated pneumonia (VAP) is the leading cause of mortality attributable to nosocomial infections and has the greatest impact on morbidity and mortality of patients hospitalised in the intensive care unit (ICU). Its incidence ranges from 9 to 67% of patients intubated and from 4.4 to 15.2 cases per 1,000 days of mechanical ventilation (MV) are reported.

Risk factors for VAP are numerous and are divided into modifiable and non modifiable (Table 1). These are further classified as early or late, depending on whether they develop in the first 4 days of MV or later. The organisms responsible for early VAP are those that usually produced community-acquired pneumonia, and those responsible for late VAP are usually multirresistant organisms.

The attributable mortality, which is influenced by a large number of factors, may be higher than 50%, and is higher still in the group of patients with bacteraemia or infections by Pseudomonas aeruginosa or Acinetobacter sp.
Several authors have shown an increase in ICU stay due to VAP of between 4.3 and 13 days.\cite{13,14,17} The cost for each VAP is estimated between €9,000 and €31,000\cite{2,3,13,18}.

Several authors have reported a decrease of 44.5 to 59% in the incidence of VAP by applying the Ventilator Bundle, which is a group of simple interventions applied jointly, as well as a reduction in days of MV and stay in ICU and in hospital.\cite{19-21}

Blot et al.,\cite{22} in the EVIDENCE study, conducted a questionnaire on knowledge of the guidelines for VAP prevention among nursing professionals. Respondents obtained an overall score of 41.2% correct responses.

Different studies have assessed the compliance with these guidelines. Rello et al.\cite{23} reported a breach of non-pharmacological guidelines by 19.6% of medical staff. The most common causes of non-compliance were disagreement with the results of the trials, unavailability of resources, and cost. With regard to nurses, Ricart et al 24 reported a 22.3% lack of adherence to guidelines. The most common reasons were the unavailability of resources, patient discomfort, disagreement with the results of trials, fear of side effects, and cost.

At least 2 multicentre studies have evaluated the performance of non-pharmacological measures and found high compliance, although there are differences between them, as shown in Table 2.\cite{25,26}

To conclude, the importance of disseminating preventive measures of VAP in order to improve results is evident.

In this article we review non-pharmacologic measures, which are cheaper and are mostly easy to implement, given the importance of dissemination to improving the consequences of VAP (Table 3).\cite{27,28}

### General Measures for Infection Control

These measures have been aimed at preventing cross-transmission and to optimize the use of invasive devices.\cite{29-31} Among the strategies to prevent VAP are a program of strict infection control that includes education of the healthcare team, proper disinfection of hands, the use of barrier methods and a microbiological surveillance protocol.\cite{2,32,33}

#### Hand Hygiene

The VAP-causing organisms, in particular gram-negative bacilli and Staphylococcus aureus, are those of the hospital environment and transmission to patients often occurs after colonisation of the hands of health-care personnel.\cite{34-36}

The guidelines for hand hygiene in health facilities of the Centres for Disease Control and Prevention report that, according to several observational studies, compliance with hand washing recommendations among health care workers is low, around 40%.\cite{37,38} Bonten et al.\cite{39} reported that compliance with this measure is lower among physicians (nurses: 40%; physicians: 25%). However, the use of alcoholic solutions has increased compliance (48 to 66%) and has decreased the rate of nosocomial infections (from 17 to 9.5%).\cite{39}

#### Appropriate Ratio of Health Personnel

Needleman et al.\cite{40} found a strong association between a greater number of care hours per head nurse and a decrease in the incidence of 5 side effects –urinary tract infection, high digestive haemorrhage, nosocomial pneumonia, shock or cardiac arrest and “failure to

### Table 1
Risk factors for ventilator-associated pneumonia\cite{4,7}

<table>
<thead>
<tr>
<th>Modifiable factors</th>
<th>Overall</th>
<th>University hospitals</th>
<th>Non-university hospitals</th>
<th>Hospital beds</th>
<th>ICU beds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R (n = 24)</td>
<td>S (n = 28)</td>
<td>R (n = 9)</td>
<td>S (n = 15)</td>
<td>R (n = 4)</td>
</tr>
<tr>
<td>Change of respiratory tubing = 72h</td>
<td>96.5</td>
<td>71</td>
<td>100</td>
<td>80</td>
<td>94</td>
</tr>
<tr>
<td>Hot water humidifiers/ humidifier</td>
<td>57</td>
<td>96</td>
<td>67</td>
<td>100</td>
<td>47</td>
</tr>
<tr>
<td>Use of open suction equipment</td>
<td>26</td>
<td>96.6</td>
<td>45</td>
<td>93</td>
<td>7</td>
</tr>
<tr>
<td>Use of open and closed suction equipment</td>
<td>59</td>
<td>45</td>
<td>73</td>
<td>75</td>
<td>73</td>
</tr>
<tr>
<td>Subglottic suction equipment</td>
<td>41</td>
<td>0</td>
<td>22</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Daily endotracheal cuff pressure control</td>
<td>74</td>
<td>58</td>
<td>67</td>
<td>47</td>
<td>81</td>
</tr>
<tr>
<td>Inclined position</td>
<td>75.5</td>
<td>92.5</td>
<td>78</td>
<td>93</td>
<td>73</td>
</tr>
<tr>
<td>Non-invasive ventilation as first line of treatment</td>
<td>75.5</td>
<td>70</td>
<td>78</td>
<td>71</td>
<td>73</td>
</tr>
</tbody>
</table>

Values are expressed as percentages. R: De Rosa et al.; S: Smith et al.; ICU: Intensive Care Unit.
rescue\(^a\) (death of a patient associated with a complication)- and hospital stay.

Cho et al.\(^{46}\) in a retrospective study that included 124,204 patients, concluded that the overload of work for the nursing staff contributes to errors in infection control measures such as hand disinfection and isolation of patients infected with multiresistant organisms.

The involvement of respiratory therapists facilitates the success of educational programs as well as the implementation of protocols to reduce the incidence of VAP.\(^{42}\) The recommended nurse:patient ratio is 1:1. Furthermore, skilled respiratory therapists should intervene in the ICU in order to share responsibilities and work together.

Avoiding Unnecessary Inpatient Transfers

It is often necessary to move the MV patients from the ICU to other areas of the hospital for diagnostic tests and treatments. Patients may remain in a supine position for long periods of time and the ventilator tubing is often manipulated, which facilitates the aspiration of contaminated secretions. The intra-hospital transfer of patients with MV increases the risk of developing VAP.

At least 2 studies report that of patients who had at least one transfer out of ICU, 24–26% had VAP, while only 4–10% of non-transferred patients had VAP (\(p = 0.001\)).\(^{43,44}\) Nevertheless, no pathophysiological cause has been established that explains these findings. It is recommended that when transfer of these patients is necessary, preventive measures are taken such as suspending enteral nutrition 4h prior to transfer, preventing ventilator tubing manipulation that can lead to aspiration of condensation into the lower airway and, if not contraindicated, transferring the patient in an inclined position.

Use of Non-invasive Ventilation (NIV)

Intubated patients have up to 21 times greater risk of acquiring nosocomial pneumonia than patients without an artificial airway.\(^{45}\) In addition to the depression of patient’s immune system defences, the insertion of an endotracheal tube is an invasive manoeuvre that can cause injury to the tracheal mucosa and eliminate the cough reflex. This leads to the accumulation of subglottic secretions generated by bacterial inoculants and facilitates their entry into the lungs.\(^{46–48}\)

The guidelines of the American Thoracic Society/Infectious Disease Society of America recommend NIV as an alternative for patients with acute exacerbations of chronic obstructive pulmonary disease or hypoxemic respiratory failure, and for some immunocompromised patients with respiratory failure, pulmonary infiltrates and fever. The evidence shows a resulting decrease in the incidence of nosocomial pneumonia and mortality.\(^{1,49,50}\)

The use of NIV to prevent reintubation after failed extubation is a measure being challenged. In a multicentre study in 37 centres in 8 countries, results showed that the application of NIV to patients with extubation failure did not prevent the need for reintubation or reduced mortality. However, the time of reintubation was higher in patients treated with NIV.\(^{51}\) Nevertheless, this may be an alternative for extubation in patients with hypercapnia.\(^{52–55}\)

Early Disconnection from Mechanical Ventilation

Although it is not always possible to avoid endotracheal intubation, there must be a strategy for its withdrawal. The reduction of MV time can reduce the incidence of VAP significantly and also reduce costs.\(^{56,57}\) Uncontrolled studies have

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**Table 3**

Prevention of Ventilator-Associated Pneumonia (VAP). Summary of non-pharmacological measures

<table>
<thead>
<tr>
<th>Non-pharmacologic measures</th>
<th>ATS/IDSA 2005(^5)</th>
<th>CDC 2003(^3)</th>
<th>ETF 2001(^7)</th>
<th>CCCS 2004(^4)</th>
<th>Comments and recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>General measures for infection control</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Not specified</td>
<td>Yes. Group education microbiological monitoring</td>
</tr>
<tr>
<td>Adequate ratio of health personnel</td>
<td>Yes</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>An adequate nurse:patient ratio (1:1) is proposed as well as an ICU-trained respiratory therapist</td>
</tr>
<tr>
<td>Avoid unnecessary inpatient transfers</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>If necessary, take measures to prevent VAP</td>
</tr>
<tr>
<td>Use of non-invasive mechanical ventilation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes. Alternative for decompensated COPD, hypoxic respiratory failure and some immunocompromised patients</td>
</tr>
<tr>
<td>Early disconnection from mechanical ventilation</td>
<td>Yes</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Yes. Termination of daily sedation, implement guidelines for early extubation</td>
</tr>
<tr>
<td>Endotracheal/orogastric intubation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes. Endotracheal and orogastric intubation</td>
</tr>
<tr>
<td>Prevention of formation of biofilm or biolayer</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Should be investigated</td>
</tr>
<tr>
<td>Drainage of subglottic secretions</td>
<td>Yes</td>
<td>Yes</td>
<td>Should be investigated</td>
<td>Yes</td>
<td>Yes. Especially in ICUs where the incidence of VAP is high</td>
</tr>
<tr>
<td>Tracheal cuff pressure control</td>
<td>Yes</td>
<td>Not specified</td>
<td>Yes</td>
<td>Not specified</td>
<td>Yes. At least 20cmH(_2)O. However, there may be leakage of secretions</td>
</tr>
<tr>
<td>Avoid changing or handling the respirator tubing</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes. Only change them when they are visually contaminated</td>
</tr>
<tr>
<td>Inclined position</td>
<td>Yes</td>
<td>Yes</td>
<td>Should be investigated</td>
<td>Yes</td>
<td>Yes. Maintains 30-45(^\circ) all the time</td>
</tr>
<tr>
<td>Kinetic beds</td>
<td>Yes</td>
<td>Not specified</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes. Indicated for postoperative and neurological patients</td>
</tr>
<tr>
<td>Enteral nutrition</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Should be investigated</td>
</tr>
<tr>
<td>Gastric or post-pyloric enteral nutrition</td>
<td>Yes</td>
<td>Post-pyloric</td>
<td>Should be investigated</td>
<td>Yes</td>
<td>Should be investigated</td>
</tr>
<tr>
<td>Gastric if there is no evidence of alteration of gastrointestinal motility</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Yes, as early as possible</td>
</tr>
</tbody>
</table>

shown that following a protocol aimed at early extubation of ventilated patients decreases the duration of MV. \(^{58-61}\) Marelich et al\(^{62}\) published the results of a controlled clinical trial in 385 patients in which respiratory therapists and nurses applied a protocol for early extubation, which reduced the time of MV by 2.23 days. That same year, a meta-analysis was published that recommended the use of protocols for early withdrawal of MV with the participation of nurses and respiratory therapists in its implementation.\(^{62}\) These strategies, including daily interruption of sedation (despite being a pharmacological measure) and following a protocol for early extubation, have been shown to shorten the time of MV.\(^{42,62-65}\)

**Endotracheal/Orogastric Intubation**

It has been shown that the insertion of catheters or tubes that prevent the drainage of the sinususes for more than 48h encourages the development of nosocomial sinusitis.\(^{66,67}\) Holzapfel et al\(^{68}\) showed that, compared with nasotracheal intubation, endotracheal intubation was associated with a lower incidence of VAP. The use of the oropharyngeal airway for endotracheal intubation and orogastric tube insertion is recommended, given the decline in the incidence of sinusitis and VAP.\(^{69-72}\) A controlled clinical study showed that a systematic search for maxillary sinusitis in patients intubated via the nasotrachea may reduce the incidence of VAP.\(^{73}\) However, a systematic search for sinusitis in patients with endotracheal intubation is not recommended, since the literature is inconclusive.\(^{67,73}\)

**Prevention of Biofilm or Biolayer Formation**

In 1986, Sottile et al\(^{74}\) described the presence of a biofilm or biolayer, consisting of an aggregate of bacteria formed on the inside of the endotracheal tube that protects the organisms from the action of antibiotics and the patient's defenses. Feldman et al\(^{75}\) studied the colonisation of endotracheal tubes of patients with MV and found that all tubes had a biofilm in the distal third. Adair et al\(^{76}\) investigated the antibiotic resistance of endotracheal tube biofilm and pulmonary organisms in VAP, and concluded that 70% of patients with VAP had the same organisms in the biofilm of the tube and in tracheal secretions.

Another strategy is to prevent or reduce the formation of biofilm, which has been accomplished by the design of silver-coated endotracheal tubes.\(^{77}\) Silver prevents the formation of the biofilm, has a bactericidal action, reduces bacterial load and decreases inflammation.\(^{77}\) Rello et al\(^{78}\) reported that the use of silver-coated endotracheal tube was safe, delayed the colonisation of the endotracheal tube, reduces the formation of biofilm and decreases the bacterial load. They concluded that controlled trials are needed to establish the efficacy of the device in the prevention of VAP. In November 2007, the Food and Drug Administration approved the sale of silver-coated endotracheal tubes. In a controlled clinical trial with 2003 patients intubated for more than 24 hours, Koleff et al\(^{79}\) concluded that those with whom silver-coated endotracheal tubes were used had a lower incidence of microbiologically proven VAP (p = 0.03). Furthermore, the development of VAP was delayed with silver-coated endotracheal tubes as compared to similar non-silver tubes (p = 0.005).

**Drainage of Subglottic Secretions**

One of the main mechanisms of development of VAP is bacterial colonisation of the oropharynx and aspiration of subglottic secretions.\(^{40}\) The presence of the endotracheal tube leads to the accumulation of secretions from the oropharynx or gastrointestinal tract above the endotracheal tube cuff\(^{80}\) and, despite adequate control of cuff pressure, there may be aspiration.\(^{81}\) It is therefore logical that continuous suctioning of subglottic secretions could prevent the onset of VAP. For this purpose, an endotracheal tube with an additional dorsal canal was designed to allow continuous or intermittent aspiration of subglottic secretions (HI-LO Evac-tube, Mallinckrodt, Hazelwood, Missouri, USA). At least 5 controlled clinical trials and a meta-analysis have shown a decrease in the incidence of VAP, especially early onset, but not in mortality, ICU stay or time of MV.\(^{82-85}\) It is important to note that the back channel for aspiration of secretions can become clogged. Rello et al\(^{86}\) observed a dysfunction in continuous aspiration of secretions in the tube in 34% of patients. Furthermore, a recent publication that investigated the cause of this dysfunction found that the most common cause was prolapse of the tracheal mucosa through the subglottic suction port, which exposes the patient to the risk of tracheal injury in that area.\(^{87}\) This study was conducted in patients with continuous aspiration of subglottic secretions, so it remains to be seen whether this dysfunction occurs with intermittent suction.

Based on limited evidence, there is the Microcuff\(^{88}\) endotracheal tube, which incorporates an ultra-thin polyurethane cuff (7μ, as compared to 50μ in conventional cuffs) and provides a better airway seal, thereby reducing the formation of folds when the cuff is inflated.\(^{82}\) On the other hand, the SealGuard Evac endotracheal tube (Mallinckrodt) incorporates a polyurethane cuff and suction of subglottic secretions.\(^{89}\) A prospective, randomised study of 280 patients compared the conventional tube with the SealGuard Evac endotracheal tube (Mallinckrodt), and found a significant 3-fold decrease in the incidence of early and late VAP using intermittent subglottic secretion drainage.\(^{90}\)

In a randomised study, Bouza et al\(^{90}\) compared conventional suction of subglottic secretions continuously in patients undergoing cardiac surgery, and concluded that patients with more than 48 hours of MV and subglottic suctioning had a lower incidence of VAP (p = 0.03) and a decrease in the use of antibiotics (p < 0.001).

**Endotracheal Cuff Pressure Control**

Several central features of the endotracheal tube include sealing the airway in such a way that does not allow air leakage, not compromising the perfusion of the tracheal mucosa, and preventing the passage of subglottic secretions to the lower airway.\(^{47,90,91}\) Conventional high-volume, low pressure endotracheal cuffs cannot prevent microaspiration even with pressures up to 60cmH\(_2\)O.\(^{92}\) Despite automatic pressure control of the balloon, there may be passage of secretions into the lower airway.\(^{93}\) Given the available information, we recommend keeping the endotracheal cuff balloon pressure between 20 and 30cmH\(_2\)O, although microaspiration prevention is not ideal, since cuff pressures above 30cmH\(_2\)O can cause tracheal injury.\(^{15,94-97}\)

**Prevent Changes or Manipulations of the Ventilator Tubing**

The condensation that appears in the ventilator tubing that uses humidifiers, especially hot water, runs the risk of contamination. Craven et al\(^{88}\) showed a higher incidence of VAP in patients whose ventilator circuits were changed every 24 hours as compared with those for whom the change was made at 48h. Koleff\(^{88}\) then reported...
that changing ventilator tubing every 7 days did not increase the incidence of VAP, but it did increase costs.

Appropriate procedures must be implemented to drain condensation and prevent medical personnel from facilitating movement of condensation to the lower airway due to patient movements or by the nozzles. As a result, it is recommended to change them when they are visually contaminated with blood, vomit or purulent secretions. With regard to hot water humidifiers and heat and moisture exchangers, the latter can reduce the build-up of condensation and the colonisation of the tubing, but has not been associated with a decreased incidence of VAP.

**Inclined Position**

At least 3 radioactive tagging studies of stomach contents have shown that gastric reflux and subsequent aspiration in patients with MV could be avoided by placement in an inclined position. The supine position facilitates the aspiration of subglottic secretions, especially when the patient is receiving enteral nutrition. Drakulovic et al. demonstrated the benefit of the inclined position (45°), which decreased the rate of orogastric aspiration and the incidence of VAP (3 times less). A tendency toward decreased mortality was observed as compared with the neutral supine position (0°). Recently, Van Nieuwenhove et al., in a controlled clinical trial, questioned the feasibility of keeping patients in an inclined position (45°) continuously and its usefulness in preventing VAP. In Holland 221 patients from four ICUs were randomised into 2 groups: one with the head at 45° and the other at 10°. The goal of maintaining the head at 45° for 85% of the time was not achieved, and the difference obtained between the 2 groups (28 versus 10°) did not prevent the development of VAP.

The inclined position is recommended, especially in patients receiving enteral nutrition, due to the low cost that this intervention requires, its easy implementation and its established efficacy.

**Kinetic Beds**

Patients hospitalised in the ICU are, due to confinement to bed, at greater risk of pulmonary complications (atelectasis, poor handling of secretions, etc.). The use of kinetic beds has been proposed, which allows continuous rotation of these patients in order to decrease the incidence of VAP. Controlled clinical trials have shown a reduced risk of VAP in surgical and neurosurgical patients, but not in medical patients. However, there are barriers to the use of these beds: the higher cost, the possibility of disconnection of intravenous catheters and the difficulty in controlling pressure zones.

**Enteral Nutrition**

It is well known that malnutrition in critically ill patients causes damage to the immune system, dysfunction of the respiratory impulse and respiratory muscle weakness, leading to prolonged ventilator dependency and increased morbidity and mortality. In addition to being associated with a longer hospital stay, although no controlled clinical trials demonstrate significant and permanent gains in important clinical outcomes such as duration of mechanical ventilation, the ICU stay and nutritional support is considered an integral component of what should be the optimal treatment of patients in the ICU.

However, this treatment is not without complications. Enteral nutrition has been considered a risk factor for VAP because of the possibility of aspiration of gastric contents. A recent publication describes the establishment and monitoring of an enteral nutrition protocol, including the inclined position (> 30°), which achieved the goal of enteral nutrition in 85% of patients (78% before the protocol) and the incidence of VAP was reduced from 6.8 to 3.2 per 1,000 days of MV.

In a systematic review of the medical literature that compared enteral with parenteral nutrition in critically ill patients with respect to case development, there was no statistically significant difference in mortality, but there was a significant increase in infectious complications such as VAP, aspiration pneumonia, urinary tract infections, bacteraemia, intra-abdominal abscesses and cathereter-associated sepsis, as well as increases in costs.

A recent meta-analysis of 11 controlled clinical trials conducted in the ICU, which evaluated mortality, the risk of aspiration and pneumonia, found no significant differences in the evolution and concluded that, in critically ill patients without evidence of gastrointestinal dysmotility, the use of post-pyloric nutrition not associated with clinical benefits.

**Conclusions**

This article reviews the evidence related to non-pharmacologic measures that have demonstrated an impact on the prevention of VAP. It is recommended to implement some of these interventions jointly to achieve better results.

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**Conflicts of Interest**

Dr. Restrepo is a speaker for Ortho-McNeil-Janssen, Johnson & Johnson, Pfizer, Inc. and Covidien BARD. He also belongs to the advisory committee of Ortho-McNeil-Janssen and Johnson & Johnson.

**References**


