How can silver nanotechnology improve tracheostomy practice and safety?

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1. Tracheostomy tubes. Current cleaning practices

Tracheostomy tubes are used to facilitate the administration of positive-pressure ventilation, to provide a patent airway in patients with an upper airway obstruction (Hess, Altobelli, 2014).

Manufacturer recommended cleaning procedures include manual brushing followed by rinsing with saline solution, neutral tensides, sterile water as well as using cleaning swabs (Leonhard,2016).

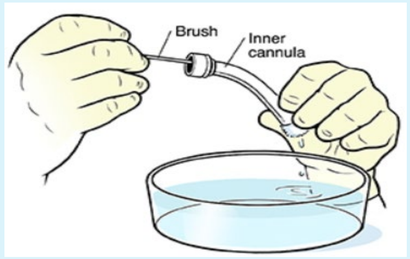

Figure1.Manual Cleaning of tracheostomy tubes(St. Luke's, 2024)

2. Problem identified. Ventilator Associated Pneumonia(VAP)

- Recommended cleaning processes provide only an average of 2log10 microbial reduction, which is classified as low efficacy and poor reliability (Leonhard, 2016).
- Ventilator Associated Pneumonia (VAP) occurs in 25–56% of all mechanically ventilated patients and has a 25–45% mortality rate (Mehta,Bhagat,2016).
- Patients who develop VAP incur ≥$10,019 in additional hospital costs in the UK (Safdar et.al.,2005), and an additional $40 000 in the US (Kollef, 2008).
- VAP development leads to prolonging the mean durations of mechanical ventilation from 4.7 to 14.3 days, of Intensive Care Unit stay from 5.6 to 11.7 days, and of hospital stay from 14.0 to 25.5 days (Kollef, 2008).
- COVID-19 Pandemic worsened VAP implications (Jones et.al., 2022).

3. Possible solution. Silver NPs coating

- Active antimicrobial-coatings are an innovative method to prevent infection of medical equipment(Chen, 2022).
- Silver nanoparticles are silver particles ranging in size between 1 and 100 nanometers.
- Coating enhances the advantages of the nanoparticles by increasing the stability of AgNPs through the electrosteric stabilization among particles and decreasing their agglomeration.
- Coating prevents cytotoxic effect of AgNPs against living cells (Fahmy et.al., 2019).

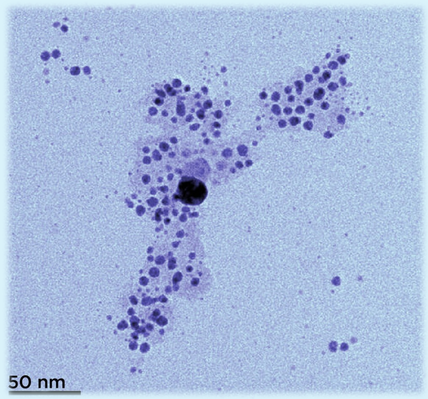

Figure2. Electron micrograph of Silver nanoparticles.(National Institute of Standards and Technology,2011)

4. How do Silver NPs work? Crucial physiochemical properties

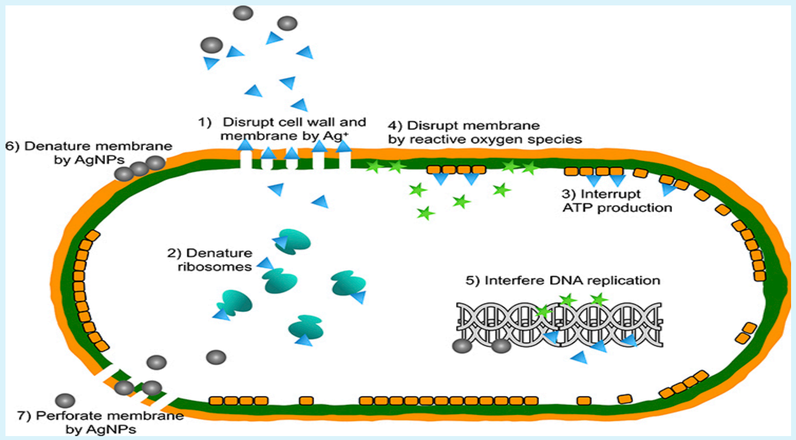

Figure3. The antibacterial actions of silver nanoparticles (AgNPs) (Yin et.al., 2020)

- Large surface area to volume ratio that results in higher surface exposure to the microbes (Deshmukh,2019).
- Electrostatic attraction and affinity to sulfur proteins allow AgNPs to adhere to the cell wall and cytoplasmic membrane and enhance its permeability which leads to disruption of the bacterial envelope.
- Small size allows AgNPs' uptake into cells, that alter DNA replication, denature ribosomes, interrupt ATP production (Yin *et al.,*2020).

5. Advantages

- AgNPs possess a broad spectrum of antibacterial, anti-fungal and antiviral properties (Yin et al., 2020).
- Currently, over 500 tons of silver nanoparticles are being produced a year (Bruna et al., 2021).
- There are cost-effective and eco-friendly biological methods to make AgNPs, using bacteria, plants, fungi and algae, reducing biotoxicity (Lazov, Ghalot and Teirumnieks, 2021).
- By using lignin and polyvinyl alcohol, a hydrogel was formulated with AgNPs synthesized in situ, showing high antimicrobial activity against *E. coli* and *S. aureus*, with almost 100 % of the bacteria killed after 10 h of treatment (Tang et al., 2023).
- AgNPs are highly reactive so can be combined with many organic materials to exhibit better antimicrobial activity and biocompatibility.

6.Limitations

• Biological methods involve complex processes and other methods that might produce hazardous waste (Bruna et al., 2021)
• Some studies show that AgNPs can penetrate intact human skin (Abbasinia et .al., 2018) depending on the size of the nanoparticle.
• Bacteria could become tolerant to AgNPs without correct measurement and regulation (Bruna et al., 2021).

7. Conclusion

Artificially ventilated patients are very often prone to infection due to the difficulty to effectively clean and disinfect tracheostomy tubes. Ventilator Associated Pneumonia has a significant mortality rate and implies an extra financial and functional burden on healthcare systems around the world.

Silver nanoparticles appear to be a highly efficient form of tracheostomy tube coating due to their chemical properties that allow them to adhere to the bacterial cell wall and disrupt it. Despite a few limitations, silver nanoparticles are manufactured at an industrial scale, which makes them reliable and readily available for use in healthcare.

8.Literature cited