Real-Time Feedback during Lung Ventilation of Tc99m-labeled Carbon Nano-particles with Topical Scintillation Detectors

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2020 SNMMI Mid-Winter
and ACNM Annual Meeting

Hi, I'm Josh Knowland and this is a presentation about real-time feedback during lung ventilation of Tc99m-labeled carbon nano-particles using topical scintillation detectors.

Disclosures

Josh Knowland – employee of Lucerno Dynamics

Mathew Farag – employee of Cyclopharm

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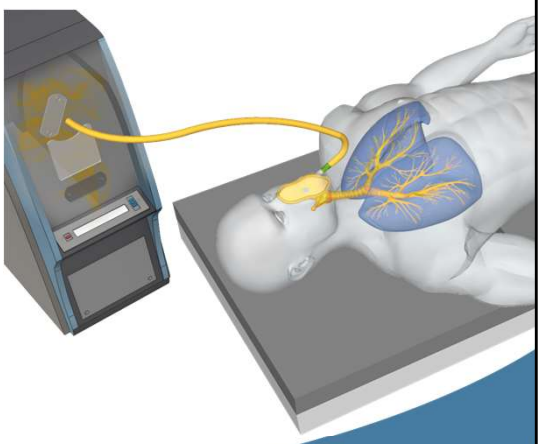
Our disclosures

Background

About Technegas™

- An ultra-fine dispersion of Tc99m-labelled carbon nanoparticles (approx. 30-500nm)
- Generator-produced by heating Tc-99m in a carbon crucible
- Hydrophobic gas-like dispersion that deposits into the alveoli
- Ventilation portion of V/Q SPECT
- Available now in much of the world
  Pending clinical trial results and approval in the US



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You're probably familiar with using radioactive gas or aerosols for doing lung ventilation imaging.

Technegas is another drug made for functional lung imaging that uses tc99m-labeled nanoparticles instead of gas. It's currently available in much of the world and is under review for approval in the US.

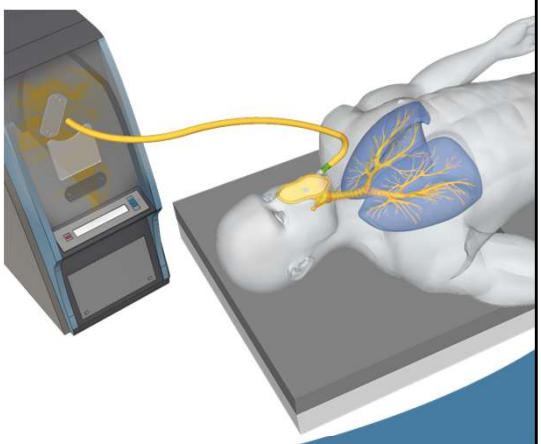
When performing the ventilation portion of a V/Q study, the inhaled activity should be high enough to produce a good quality image. But, if ventilation is performed before perfusion, too much activity can be detrimental to the perfusion imaging contrast.

There should be a balance between too much and too little activity in the lungs.

Background

Maintain Balance

- Image quality depends on monitoring inhaled activity
- Method 1: patient in the SPECT scanner
- Method 2: pancake probes with GM counter



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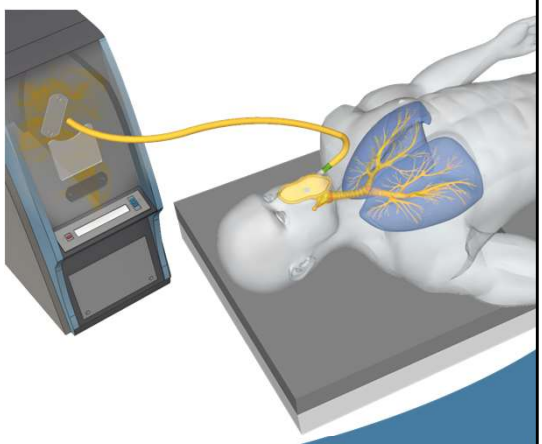
To maintain balance today, ventilation is performed while monitoring lung activity and it's stopped when a pre-defined threshold is met.

Two methods of monitoring have been used: feedback using a SPECT scanner or simple pancake probes with a Geiger counter.

Background

Drawbacks of Current Monitoring Methods

- Existing monitoring methods have drawbacks
- Contamination of SPECT scanner
- Seated vs reclined
- Variability and uncertainty of manual probing



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These methods have drawbacks, though.

First, if ventilation is performed with the patient **in** the SPECT scanner, contamination can occur if the patient exhales into the room. This could take the scanner offline while waiting for the Tc99m to decay.

Secondly, some recent papers suggest that respiratory mechanics vary significantly between seated and reclined, and that *seated* ventilation may be the preferred method. Not many SPECT scanners will accommodate that.

And third, manual probing may include unintended variability due to technique and the spatial relationship to the lungs.

Background

A Better Option

- Perform ventilation outside of the SPECT scanner
- Measurement repeatability
- Monitor *and record* inhaled activity

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We propose the solution is to perform ventilation monitoring outside of the SPECT scanner using detectors that allow for measurement repeatability, and not only monitoring, but also recording of the inhaled activity.

Background

About Lara®

- Topical uptake probe system consisting of single-crystal scintillation detectors
- Held on the patient's skin with atraumatic, easily removable adhesive pads
- Measures incident radiation in counts per second
- Displays real-time count rates as well as time-activity curves
- FDA Listed* and CE marked

*This presentation describes simulations of an investigational use of the Lara device.

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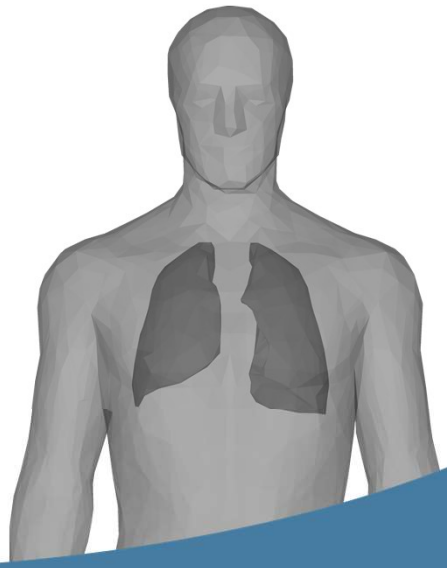
The Lara system consists of multiple topically applied scintillation detectors that do just that.

The detectors are placed on the patient's skin with atraumatic adhesive pads and provide a real-time readout in counts per second - every second.

The system also supports storage of the measurement data in PACS as a time-activity curve.

Objective

- Investigate if topical scintillation detectors could provide real-time lung activity feedback



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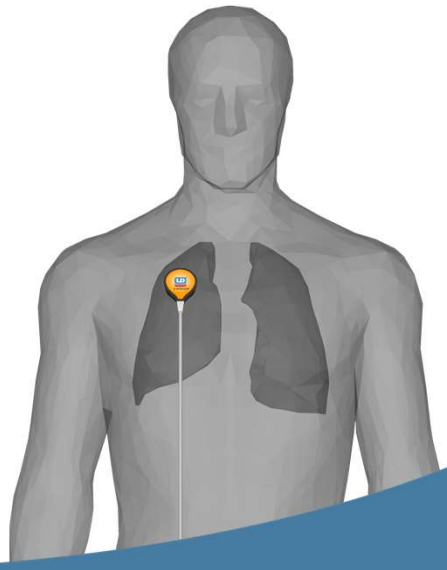
For this work, our objective was to investigate whether these detectors would be able to dynamically measure ventilation of Technegas.

Methods

Monte-Carlo Simulation

- Monte-Carlo simulation using the GATE Geant4 Framework
- Anthropomorphic human models created from the BodyParts3D database
- Geometric models of the Technegas generator
- Geometric and instrumentation models of the Lara detectors
- GATE's standard material definitions



http://www.opengatecollaboration.org/
https://lifesciencedb.jp/bp3d/

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We used the GATE monte-carlo framework which is a script-based front-end to the GEANT4 simulation package.

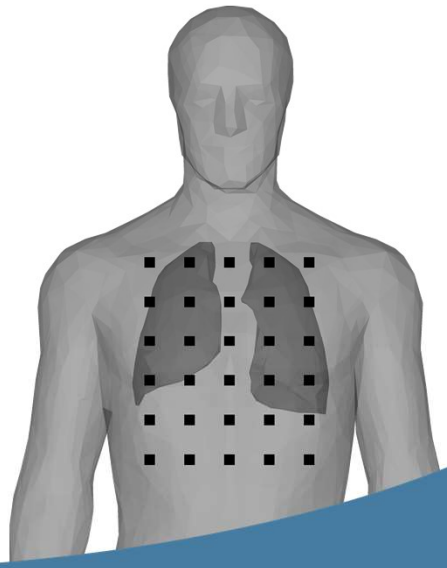
3D computer models were created for patient anatomy and detector hardware.

And GATE's standard material definitions were used for not only tissue and organs, but also the detectors.

Methods

Simulation Set-up

- Multiple detectors placed on the human phantom
- Lung activity of 1 mCi Tc99m
- Technegas generator held 25 mCi
- Simulation run for 10 seconds and counts summed for each detector



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Virtual detectors were placed onto the chest of our human model to investigate which locations might provide the best information about inhaled activity. Each black square you see here is a detector location that was investigated.

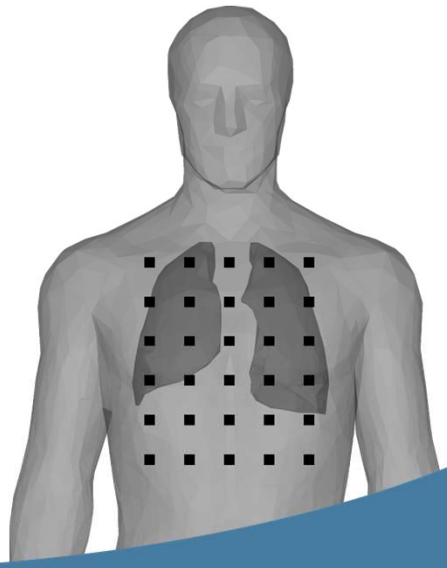
In the simulation, the lungs contained 1 mCi of Tc99m with a uniform distribution and the Technegas generator contained bulk storage of 25 mCi.

The simulation was run for 10 seconds and each detector recorded incident energy which was converted into counts.

Results

Simulation Outputs

- Resulting detector outputs were analyzed
- Counts differentiated based on their source – left lung, right lung, or generator
- Generator bulk dose counts were negligible – 0.5%



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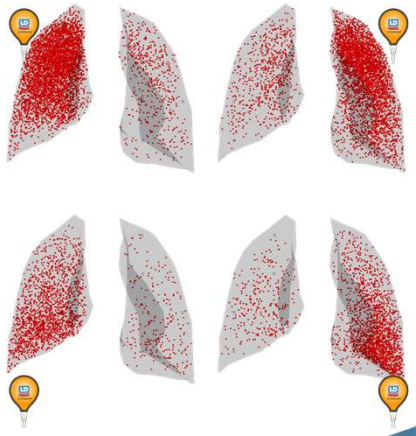
We analyzed the detector outputs in terms of amplitude as well as the origin of each hit – left lung, right lung or bulk dose.

The generator's bulk dose contributed negligible counts for all detectors - at most a half a percent of the total counts.

Results

Sensitivity

- Detector output varied based on location and proximity to lungs
- Some locations measured activity from predominantly one lung or the other
- Detector outputs ranged from 195 to 725



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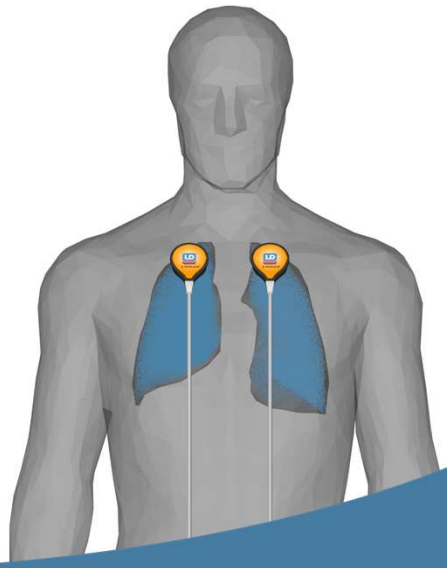
Obviously, some locations were better suited to measure one lung versus the other. Here you see the corner cases that clearly show sensitivity to different parts of the lungs.

Overall, detector outputs ranged from 195 counts to 725 counts.

We would expect the detector outputs to rise from zero to 700 or more over the course of about 3 slow, deep breaths. Each breath should cause a clear increase in detector output as the amount of sequestered activity increases.

Conclusions

- Simulated detector response suggests our objective could be met
- Preferred detector locations were the apex of each lung
- Detector placement could be aided by clavicle palpation



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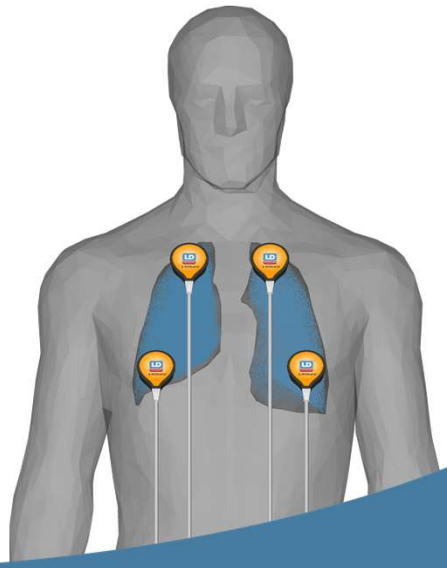
The detector locations with the best results were over the apex of each lung.
These locations not only resulted in high detector output relative to other locations but were well differentiated between left and right lung.

Additionally, the apical locations would be easily accessible for applying and removing the detectors, and the clavicles could be used as palpable reference points.

Conclusions

- Simulated detector response suggests our objective could be met
- Preferred detector locations were the apex of each lung
- Detector placement could be aided by clavicle palpation
- Multiple detectors could be used at once



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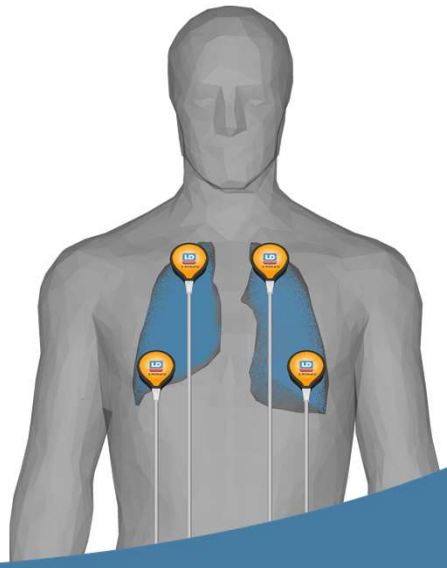
And there's no reason to use only two detectors;
Multiple areas could be monitored and recorded to confirm activity throughout the lungs.

Conclusions

- Use of detectors for real-time feedback about lung activity may be possible and useful
- Enable ventilation without SPECT
- Avoid scanner contamination
- Avoid manual process variability



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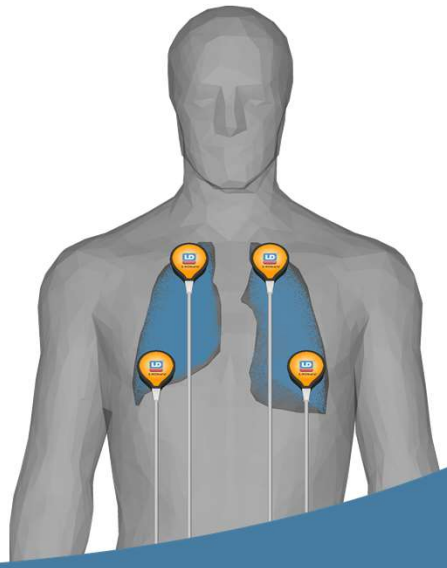
So in conclusion, it does seem that topical detectors could allow for real-time feedback about lung activity without the use of dynamic SPECT counting or manual probing. This would allow for ventilation to be performed without the risk of scanner contamination or the variability of manual processes.

Future Work

- Confirm simulations using real patients
- Compare detector output to other methods
- Determine and assess other sources of variability



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Future work on this topic should include confirmation of these results using live patients and comparison between detector outputs and those of existing methods.

Additionally, we should investigate possible sources of variability for the proposed method, such as residual activity in the bronchus, or the impact of reduced lung function.

Thank You

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401874-100155 rev 0
01/2020

Thank you for your time and attention.