Load Assistance for Reduced-Strain Sonography

A Helping Hand for Force Application During Ultrasound Scans

LARS

Patent Pending

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Motivation

90% of Ultrasound technicians (sonographers) have experienced **workplace-related pain in the past year**, and 50% have had a serious injury in their careers [1, 2]

86% find pushing into patients aggravating or **extremeley aggravating** [1]

Cardiac sonographers report pain and time off at the highest levels due to large forces, awkward postures, and longer scans [2, 3]

Existing ergonomic solution **do not target the largest source of pain**, and autonomous solutions are large, **expensive**, and aim to replace technology and sonographer.

There is a need to design a device to be used with **existing ultrasound technology** to help **reduce workplace-related pain** in cardiac sonographers without affecting workflow.

Outreach & Specifications

Stakeholders:

- 12+ Sonographers
- 3 Clinicians
- 2 Department heads
- 1 Sonography Organization

Conducted:

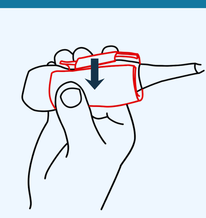
- ☑ Interviews
- ☑ Surveys
- ☑ Webinar
- ☑ Observations

Aided in informing design decisions, iteration, and target metrics

Key Requirements	Target
Force Applied	0-34.5 N
Probe Displacement Error	< 2 mm
Workspace, Orientation Coverage	95%, 60°
Setup Time	< 2 minutes

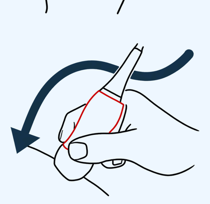
Workflow

1. Attach ultrasound probe to device



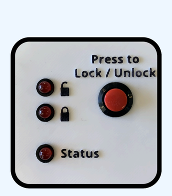
Contoured case with one-handed operation

2. Move probe against patient at a desired location and force



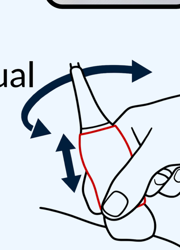
Articulated arm with passive balancing satisfies workspace requirements with weightless motion

3. Push a button to lock position/force



Simple user interface locks continuous-motion brakes in position

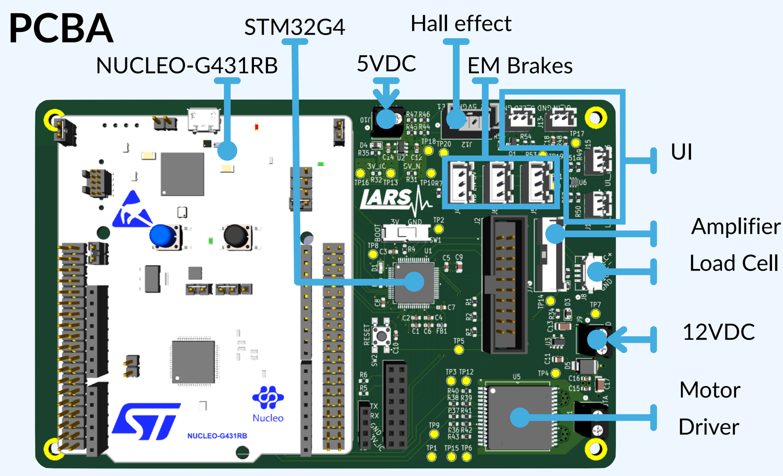
4. Perform scan as usual with freedom of orientation while a constant force is applied



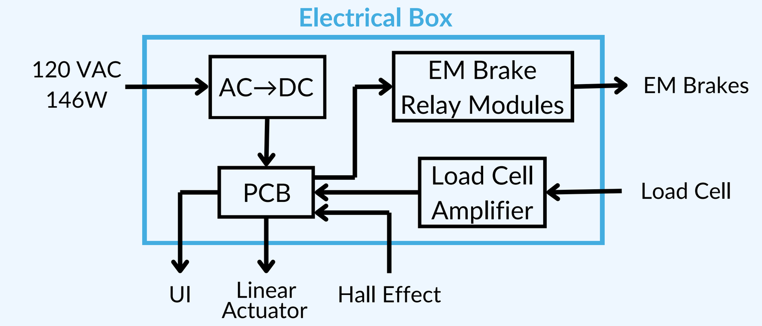
Remote center of motion allows rotation and angle change about a contact point, while the control loop dynamically adjusts position to maintain pushing force

Electrical

PCBA



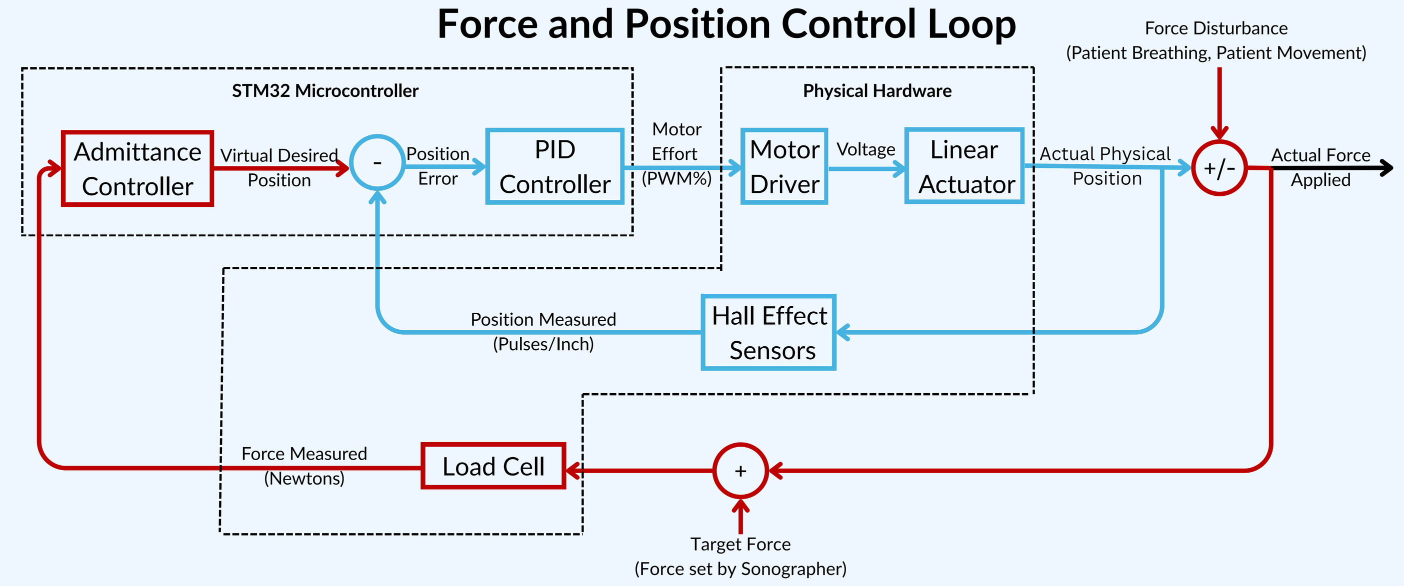
System Diagram



CSA SPE-1000 Certified

Control System

Force and Position Control Loop



The Outer Loop: Admittance Control

Handles Forces Disturbances

Virtual Damping (Speed of Reaction to External Forces)

$$M_v\ddot{x} + B_v\dot{x} + K_v x = F_{ext}$$

Virtual Mass (Perceived Weight of the Arm)

Virtual Stiffness (Sensitivity to Position Changes)

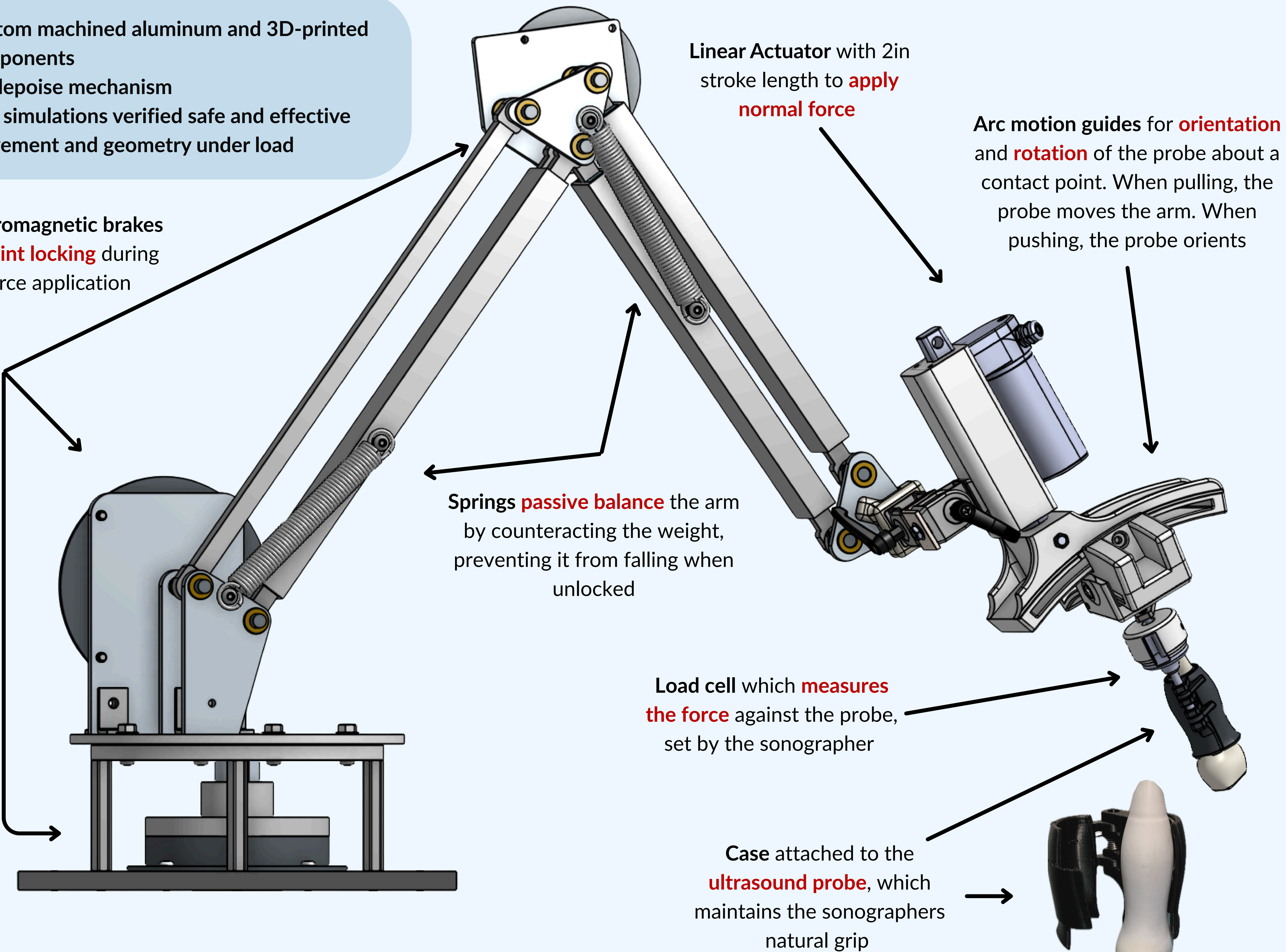
The Inner Loop: PID Control

Handles Reference Tracking

$$C_{PID}(s) = K_p + \frac{K_i}{s} + K_d s$$

Mechanical Assembly

- Custom machined aluminum and 3D-printed components
- Anglepoise mechanism
- FEA simulations verified safe and effective movement and geometry under load



Electromagnetic brakes for **joint locking** during force application

Linear Actuator with 2in stroke length to **apply normal force**

Arc motion guides for **orientation** and **rotation** of the probe about a contact point. When pulling, the probe moves the arm. When pushing, the probe orients

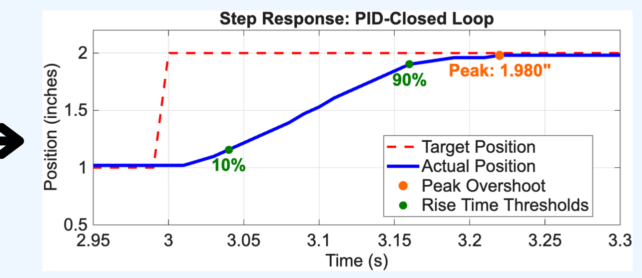
Springs passive balance the arm by counteracting the weight, preventing it from falling when unlocked

Load cell which **measures the force** against the probe, set by the sonographer

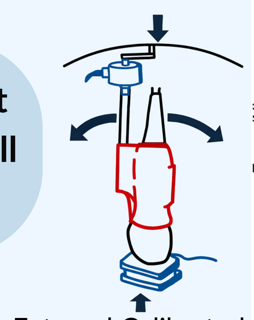
Case attached to the **ultrasound probe**, which maintains the sonographers natural grip

Testing & Results

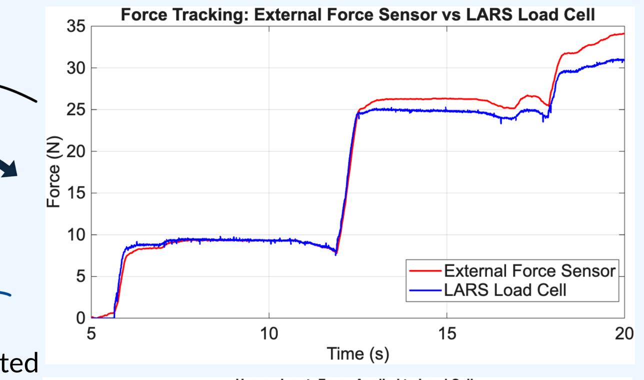
Rise Time: 120 ms
Damping Ratio: 1
Critically Damped



Simulated patient-felt force vs. LARS load cell felt force

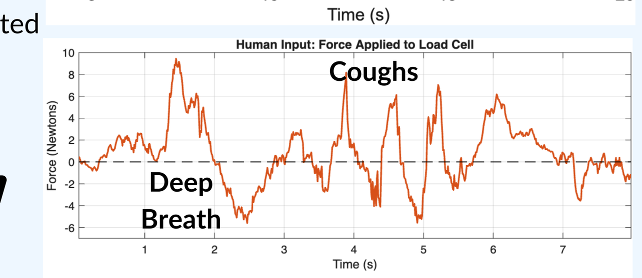


External Calibrated Load Cell

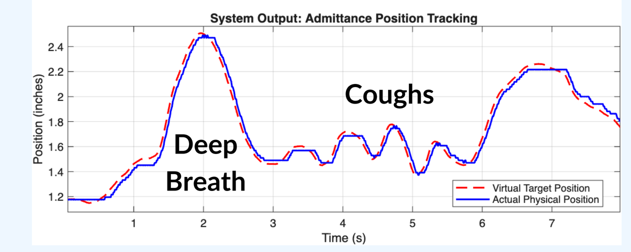


System response to patient breathing and cough

Force



Position



Impact

$56k per week of costs if a sonographer is injured [4]

$200k per Sonographer spent over a career on time off and pain relief [5]

With a minimum viable price of $4316, LARS is 30x cheaper [6] than autonomous competitors in a total addressable market of ~$800M.

Sustainable Development Goals

3 GOOD HEALTH AND WELL-BEING: 51% of Sonographers have considered quitting in the past year [7]

5 GENDER EQUALITY: Pain levels and prevelance is ~10% higher amongst females, who make up >85% of the workforce [2]

"I think it would be really nice on certain days to get, as you say, a helping hand."

Echocardiogram technician, Waterloo Regional Health Network at Queens

Conclusions

LARS effectively reduces sonographer force application requirements and adapts to disturbances to exert a steady force against a patient.

Limitations

- Size may be too large for some clinical spaces
- Some ultrasound scans not attainable (subcostal, suprasternal)

Future Work

- User testing
- Design housing
- Implement AI
- Move towards other imaging modalities

"I hope to one day see how the load bearing technology could be beneficial to vascular technology."

OAMRS Medical Sonographer

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Ontario Association of Medical Radiation Sciences

interface FORCE MEASUREMENT SOLUTIONS

PROGRESSIVE AUTOMATIONS

WRHN Waterloo Regional Health Network

CPS CARDIO PULMONARY SERVICES

[1] K. Evans, S. Roll, and J. Baker, "WRMSD Among Registered Diagnostic Medical Sonographers and Vascular Technologists," *JDMS*, vol. 25, no. 6, pp. 287–299, Nov. 2009, doi: https://doi.org/10.1177/8756479309351748.

[2] A. Hogan, "Pain levels and injuries by sonographic specialty: A research study," *JDMS*, vol. 38, no. 1, p. 875647932110441, Sep. 2021, doi: https://doi.org/10.1177/87564793211044122.

[3] N. M. Orme et al., "Occupational musculoskeletal pain in cardiac sonographers compared to peer employees," *Echocardiography*, vol. 33, no. 11, pp. 1642–1647, Aug. 2016, doi: https://doi.org/10.1111/echo.13344.

[4] O. J. Pallotta and A. Roberts, "Musculoskeletal pain and injury in sonographers, causes and solutions," *Sonography*, vol. 4, no. 1, pp. 5–12, Dec. 2016, doi: https://doi.org/10.1002/sono.12093.

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[6] S. Sahoo, "AdEchoTech's Melody lingers on to provide vital images," *The National*, Jan. 29, 2013. [Online] Available: https://www.thenationalnews.com/business/ adechotech-s-melody-lingers-on-to-provide-vital-images-1.457977.

[7] "More than Half of Vital Healthcare Workers Considered Quitting Their Jobs Over the Past Two Years - Sonography Canada," *Sonography Canada*, Jan. 31, 2024. https://sonographycanada.ca/news/more-than-half-of-vital-healthcare-workers-considered-quitting-their-jobs-over-the-past-two-years