Estimating Instrument Position in Blind 3D Space during Simulated Retropubic Trocar Passage

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Introduction

- Retropubic midurethral sling surgery
  - **blind passage of sharp trocars**
    - cephalad to the pubic symphysis
    - injuries to the urethra, bladder, bowel, and blood vessels.[1,2]
- **Objective**: determine if surgical novices are more likely than experts to be unaware of their surgical instrument location in space.

Methods

Participants

- Expert and novice surgeons

Experiment

- simulated trocar passes (Figure 1)
- nontransparent pelvis simulation platform[3]
- tip of the trocar tracked relative to the internal vital organs
  - 8mm retroreflective motion capture markers on the trocar and model
  - twelve OptiTrack Flex 13 cameras
- Participants vocalize when they perceived the trocar tip:
  - Touches caudal aspect of the bone
  - crosses 3 planes (Figure 2)

Data Analysis

- Raw audio data transformed using the Teager-Kaiser Energy Operator (TKEO) (Figure 3)
- Onsets selected by observers for IRR calculation
- Calculated differences (Δ_{Bone}, Δ_{Turn}, Δ_{Top}, Δ_{Pop}) between vocalization times and when the trocar crossed the corresponding plane
  - Mann-Whitney, Chi-Square
- Levene's tests: differences in variability between groups

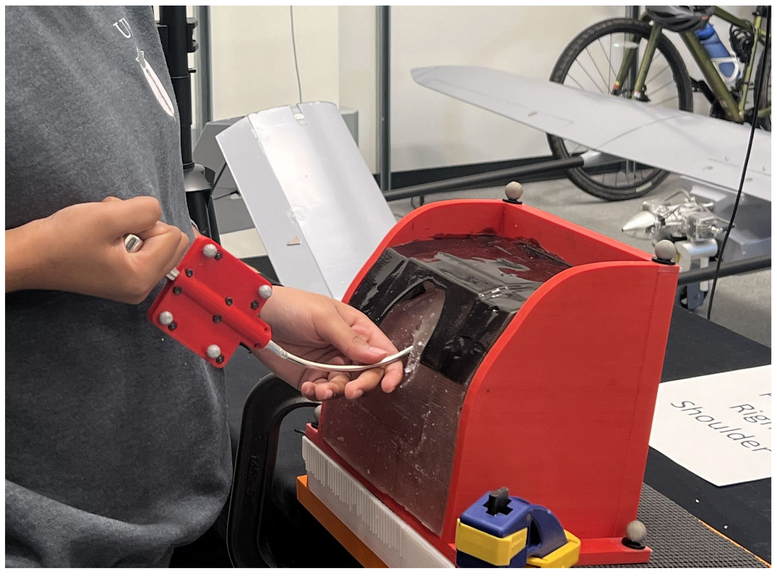

Figure 1. Experimental Setup
Participant passing the retropubic trocar through the pelvic model. The thermoballistic gel and black latex covering ensure that the procedure is blind, and the participant must use haptic cues to determine where the trocar tip is in relation to the bone. Vocalizations are recorded via microphone (not shown).

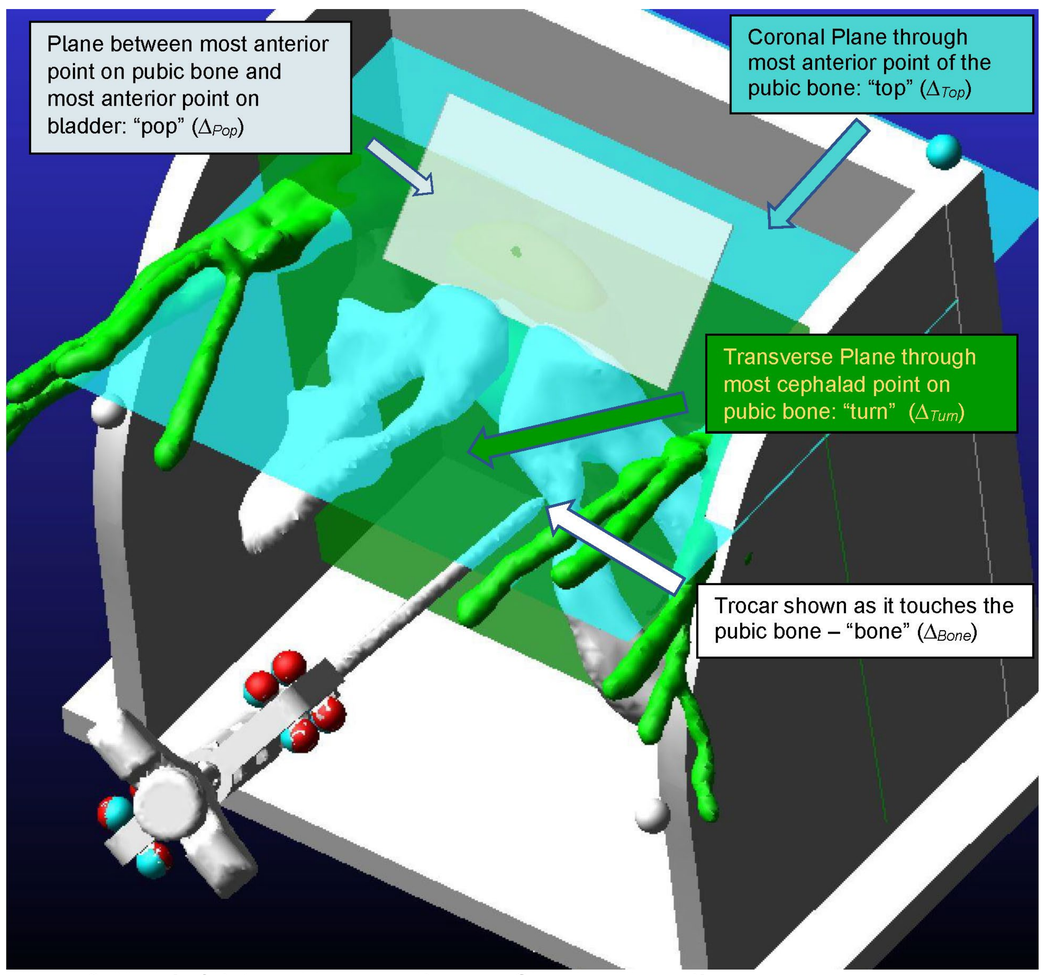

Figure 2. Model of Retropubic Trocar Passage Showing Three Planes
Three-dimensional rendering of retropubic trocar contacting the pubic bone within the pelvic model. The trocar is guided past the bone and bladder within the model, which are not visible to the participant (thermoballistic gel not shown). All three planes are indicated and described.

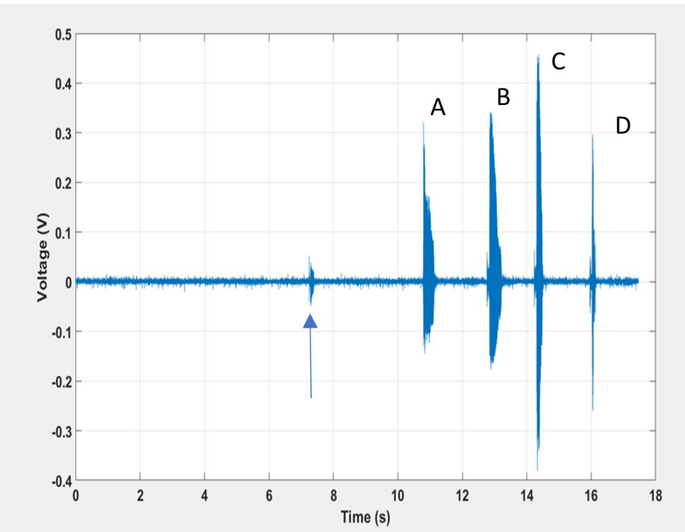

Figure 3. Audio Waveform Depicting "Bone", "Turn", "Top", and "Pop"
Representative raw audio waveform depicting the four verbal events: (A) "Bone", (B) "Turn", (C) "Top", and (D) "Pop". The audio burst indicated by the arrow is an example of an unexpected vocalization ("ok") that was excluded from analysis

Results

Six subjects, **38 trials**

- 22 expert trials
- 16 novice trials

IRR: 0.98 - 0.99

Δ_{Bone} smaller among novice surgeons (1.210 vs. 2.824 seconds, $p<.05$)

Δ_{Turn}, Δ_{Top}, Δ_{Pop}: no significant differences between novices and experts (Table 1&2)

Levene's test: no significant difference in within-subject variability of vocalization time between novice and expert surgeon

- for Δ_{Bone}, Δ_{Top}, Δ_{Turn}, or Δ_{Pop}

Power Analysis

- Assuming Δ_{Turn} = 1.25 seconds for the experts
- 100% relative increase for the novices
- two-sided alpha of 0.05
- total of 20 trials to provide 80% power

Table 1. Difference between the time when the trocar tip intersected the plane and the time of the vocalization, comparing novices versus experts

Plane	Novice (N=12)	Expert (N=22)	p	U test statistic
Δ_{Bone}	1.27 (1.84)	2.81 (1.36)	0.013	200.0
Δ_{Turn}	1.59 (2.11)	1.36 (1.45)	0.845	126.0
Δ_{Top}	0.63 (1.49)	0.54 (0.31)	0.276	101.0
Δ_{Pop}	1.36 (1.96)	1.15 (0.72)	0.557	115.0

Note: nonparametric Mann-Whitney tests on the outcome variables to compare median deltas between novice and expert surgeons. Median deltas are expressed in absolute values in seconds (SD). Δ_{Bone}, Δ_{Turn}, Δ_{Top}, Δ_{Pop} refer to the 4 planes in the simulation model.

Conclusion

- Expert and novice surgeons similar in estimation of the trocar's location relative to suprapubic bone
- The ability to assess where a surgical instrument is appears to be a fundamental skill rather than a distinguishing factor between expertise levels.

Discussion

- Teaching surgeons relying on their trainee vocalizing the location of the instrument can be reassured that their estimation is not different than what they would estimate.
- Understanding how anticipation influences the timing of vocalization in response to a stimulus is central to interpretation of our data.
- Exploring how the cognitive process of experts differs from novice surgeons could affect training and educational approaches.

Table 2. Experts according to whether their vocalization for each plane was early or late.

Plane	Early		Late		X^2 (1,34)
	Novice	Expert	Novice	Expert	
Δ_{Bone}	0%	0%	100%	100%	-
Δ_{Turn}	33.3%	22.7%	66.7%	77.3%	0.449
Δ_{Top}	58.3%	27.3%	41.7%	72.7%	3.172
Δ_{Pop}	16.7%	13.6%	83.3%	86.4%	0.057

Note: This is comparison of 12 Novice trials and 22 Expert trials, using Chi-Square tests.
P-values for Δ_{Turn}, Δ_{Top}, Δ_{Pop} were all > 0.05

References

1. Muir TW et al. Obstet Gynecol. May 2003;101(5 Pt 1):933-6.
2. Linder BJ et al. Urol Clin North Am. Feb 2019;46(1):17-30.
3. Arif MA et al. Surgery. Sep 2022;172(3):1024-1028.