Kinematic Differences between Novice and Expert Surgeons during Simulated Midurethral Sling Surgery

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Introduction

- Retropubic midurethral sling surgery
  - Blind passage of sharp trocars
  - Series of four distinct trajectory steps
  - Injuries include bladder and urethral perforations, bowel perforation, injuries to major blood vessels
  - Overall rates of injuries are significantly higher in novice surgeons [1]
- **Objective**: determine trocar temporal and kinematic differences between novice and expert surgeons.

Methods

Participants
- Expert and novice surgeons

Experiment
- Simulated MUS procedures (Figure 1)
- 15 trials per participant
- Trocar fitted with rigid body that included seven 8mm retroreflective motion capture markers
- Trocar movement recorded with a 12 camera motion capture system (OptiTrack Flex 13)

Data Analysis
- Motion data post-processed and filtered
- Multibody kinematics models in ADAMS included 3D geometries of physical simulator, trocar instrument, major blood vessels, and bladder (Figure 2)
- Motion data from experimental trials used as input to the kinematic analysis
- Landmark oriented planes corresponding to the 4 stages of the procedure created in multibody models

Outputs

Trocar tip location, time intervals for each stage, contact with bladder, iliac vessels, posterior vs anterior trocar passage

Figure 1. Experimental Setup
Participant passing the retropubic trocar through the pelvic model. Reflective markers are attached to the trocar, simulator, and the surgeon to track movement.

References

1. McLennan MT and Melick CF. Obstet Gynecol. 2003;106(5)1:933-6.

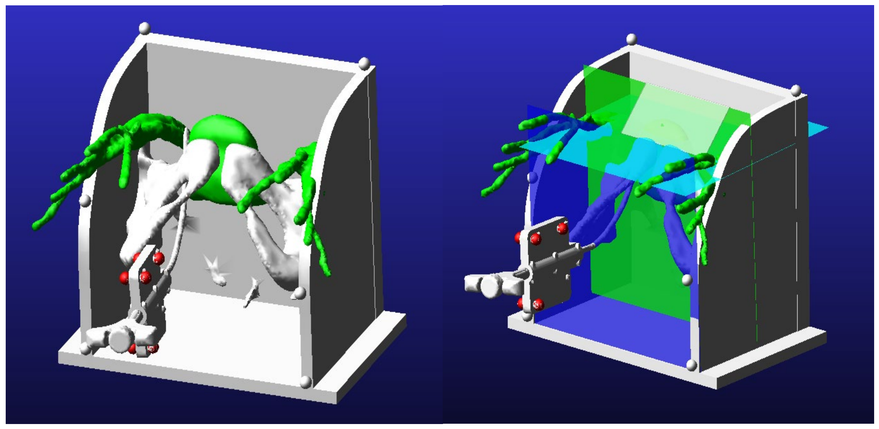

Figure 2. Multibody kinematic models
Example of the 3d kinematic model used for analysis. Experimental motion capture data is . All three planes are indicated and described.

Left Passage				Right Passage		
Direction	No bladder contact Mean (std) – mm	Bladder contact Mean (std) – mm	Significance	No bladder contact Mean (std) - mm	Bladder contact Mean (std) – mm	Significance
Medial-Lateral	13.1 (18.1)	1.3 (32.1)	0.001*	11.7 (11.3)	3.1 (19.4)	0.105
Anterior-Posterior	3.8 (19.0)	11.4 (26.4)	0.010*	6.9 (19.4)	5.7 (24.6)	<0.001*
Caudal-Cephalad	63.4 (24.9)	61.5 (25.9)	<0.001*	65.5 (26.5)	62.0 (25.7)	<0.001*

Table 1. Trocar tip trajectory excursions comparison between error free trials and bladder perforation trials (all stages).
All trocar trajectories are computed relative to an origin placed at the incision point.

Stage 3: Bladder perforations happen in stage 3 primarily so trocar tip pathways were analyzed separately for this stage.

Left Passage				Right Passage		
Direction	No bladder contact Mean (std) – mm	Bladder contact Mean (std) – mm	Significance	No bladder contact Mean (std) – mm	Bladder contact Mean (std) – mm	Significance
Medial-Lateral	19.7 (21.5)	0.5 (38.7)	0.099	15.0 (11.0)	9.5 (16.8)	0.316
Anterior-Posterior	5.0 (15.3)	4.1 (24.5)	<0.001*	3.0 (18.2)	3.4 (21.0)	0.039*
Caudal-Cephalad	84.8 (11.7)	81.2 (11.8)	<0.001*	86.5 (9.2)	82.4 (12.9)	<0.001*

Table 2. Trocar tip trajectory excursions comparison between error free trials and bladder perforation trials for stage 3.
All trocar trajectories are computed relative to an origin placed at the incision point.

Left Passage				Right Passage		
Direction	Posterior pass Mean (std) – mm	Anterior pass Mean (std) – mm	Significance	Posterior pass Mean (std) – mm	Anterior pass Mean (std) – mm	Significance
Medial-Lateral	9.1 (23.7)	13.4 (12.8)	<0.001*	8.5 (15.4)	12.6 (10.8)	0.003*
Anterior-Posterior	5.9 (21.6)	3.4 (17.2)	<0.001*	6.4 (21.5)	17.6 (26.5)	<0.001*
Caudal-Cephalad	62.8 (25.2)	51.1 (19.4)	<0.001*	64.2 (26.2)	49.0 (18.2)	< 0.001*
Total Path Length	272.4	304.2	0.262	242.1	345.3	0.0005*

Table 3. Trocar tip trajectory excursions comparison between trocar passes posterior to the pubic symphysis and incorrect anterior passes.
All trocar trajectories are computed relative to an origin placed at the incision point. Total path length is computed from incision to

Stages

- Stage 1: trocar tip from incision to pubic bone contact
- Stage 2: trocar tip from first contact to the most cephalad point of the pubic bone
- Stage 3: trocar tip form most cephalad point to the most ventral point of the pubic bone
- Stage 4: trocar tip from the most ventral point of the pubic bone to the exit point

Results

Experts – 27 error free trials, 18 bladder perforation trials (40%)
Novices – 18 error free trials, 4 bladder perforation trials, 23 passes anterior to the pubic symphysis (60% error rate)

Incidence of anterior passage was significantly different between expert and novice surgeons (Right passage: 0% vs 63.6%, p<0.001; Left passage: 0% vs 39.1%, p <0.001).

Experts contributed 14% to the total trocar pathway variation whereas 48% is attributed to novices.

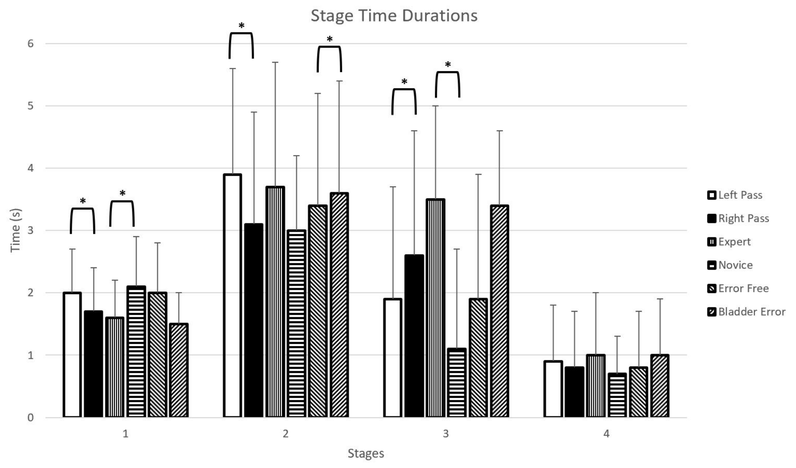

Figure 3. Temporal characteristics of trocar passage at each stage

Conclusion

- Novice error passes were predominantly anterior to the subprapubic bone
- Bladder error for the novices is lower than experts but that is primarily caused by the fact that novices had a high percentage of anterior passes which will not allow for bladder contact to occur.
- Temporal and trajectory characteristics of the trocar are related to successful trocar passes.
- Experts are much better at following a consistent trocar pathway.

Discussion

- Anterior pass error have never been reported in previous studies because statistics from OR would not include those incidences. Simulated surgeries allow us to observe a significant error in inexperience surgeons.