Seminar/Literature Review: **Surgical Instrument Ergonomics**

Surgical Instruments for Robotic Open Microsurgery

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Aim

Develop normally-open microvascular needle driver and/or forceps that can be integrated with Galen robot

1) Held at the top by the surgeon
2) Held at the middle by the robot
3) Allows for rotation about own axis
4) Ergonomic and dexterous
5) Design for manufacturability & sterilizability

Surgical Instrument Ergonomics

1) Design considerations for microsurgery
2) Tasks, models, evaluation methods (in laparoscopy)
3) Postural analysis tool

Kumar et al.,MICCAI '99

Areas for improving ergonomics

1) Tool itself - affects fingers, wrist, shoulders etc.

2) Location of tool in workspace – affects neck, eyes, overall posture

3) Environment (lighting, noise, temperature)

4) Participant numbers (nurse, endoscope holder

5) Variety, order, frequency and duration of tasks

"Suspending your keyboard from the ceiling forces you to sit up straight, thus reducing fatigue."

Paper 1: ERGONOMICS APPLIED TO THE PRACTICE OF MICROSURGERY

Patkin, M. (1977), ERGONOMICS APPLIED TO THE PRACTICE OF MICROSURGERY. Australian and New Zealand Journal of Surgery, 47: 320–329.

This paper examines five aspects of microsurgery where ergonomics is important

(i) visual feedback

(ii) accuracy of hand movement and control of tremor

(iii) the acquisition of skill

(iv) hand grip used for precise work

(v) design and care of microsurgical instruments

Handle design

Microsurgical “grip” different from “pen” grip

Three main movements:

A) Protraction, retraction B) rotation   C) pinch/trigger

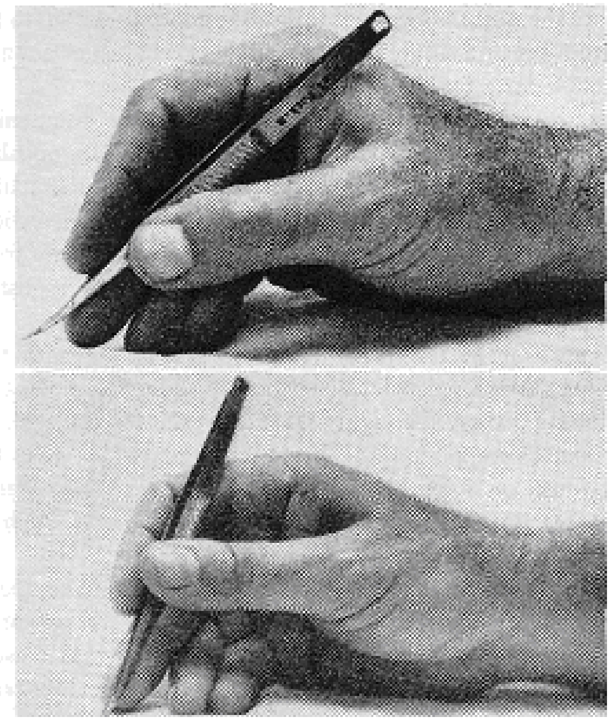
A) Length of handle – about 10 cm; the distance from fingertips to instrument tip will depend on access to the tissues at operation

B) Handle cross-section circular, milled for friction

C) Diameter of handle 5-10 mm

D) Force required for closing is 40 – 100 gm

E) Mechanical advantage : 6:1



Microsurgical vs Pen grip

Patkin et al., . ANZ 1977

Assessment

Positives:

Mentions dimensions required exactly, along with biomechanical reasons behind them

Actionable suggestions for tool and workplace design

Negatives:

Outdated paper- manufacturing has improved greatly over 3 decades

Based on conventional surgery and not robotic assisted surgery

Paper 2: Tasks ,Models and Measurement Systems (Laparoscopy)

Lee, G., Lee, T., Dexter, D., Klein, R., & Park, A. (2007). Methodological Infrastructure in Surgical Ergonomics: A Review of Tasks, Models, and Measurement Systems. *Surgical Innovation, 14*(3), 153-167.

Types of tasks:

1) **Static** – opening and closing of instruments, no motion of tool tip

2) **Simple navigation** – Operation game

3) **Manipulation** - pushing small object into small aperture, instrument-instrument rope passing, Cable passing, shape cutting, suturing, tying

Fundamentals of Laparoscopic skills (FLS)

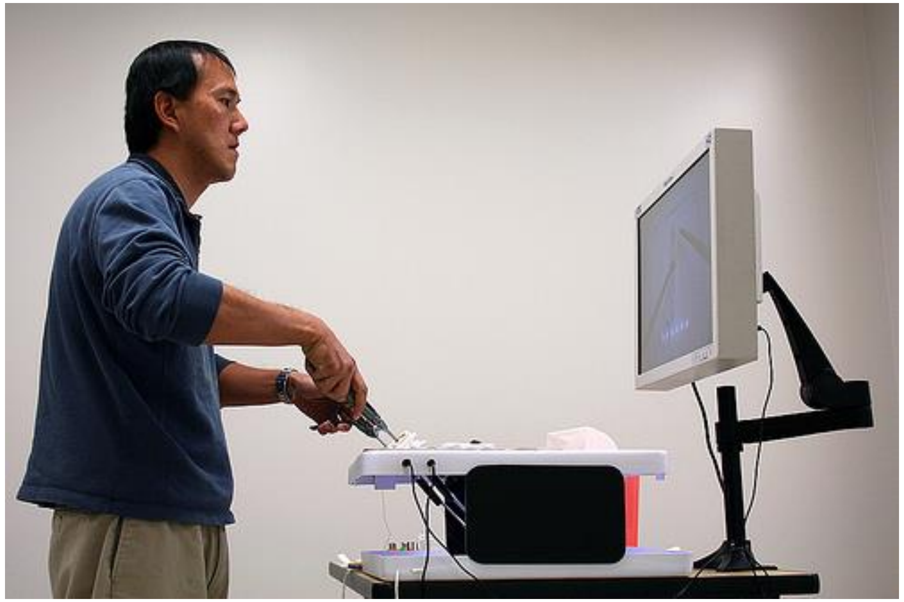
Environments for testing

1) **Operating Room-** on cadavers, phantoms

2) **Training box-** confined space roughly approximating the abdominal cavity into which ports may be placed to allow instrument access, camera within for recording

3) **Virtual Reality simulators –** visual, audio and haptic feedback

By measuring the success rate and speed of completion, we can compare the ergonomics of different instrument designs



Measurement methods

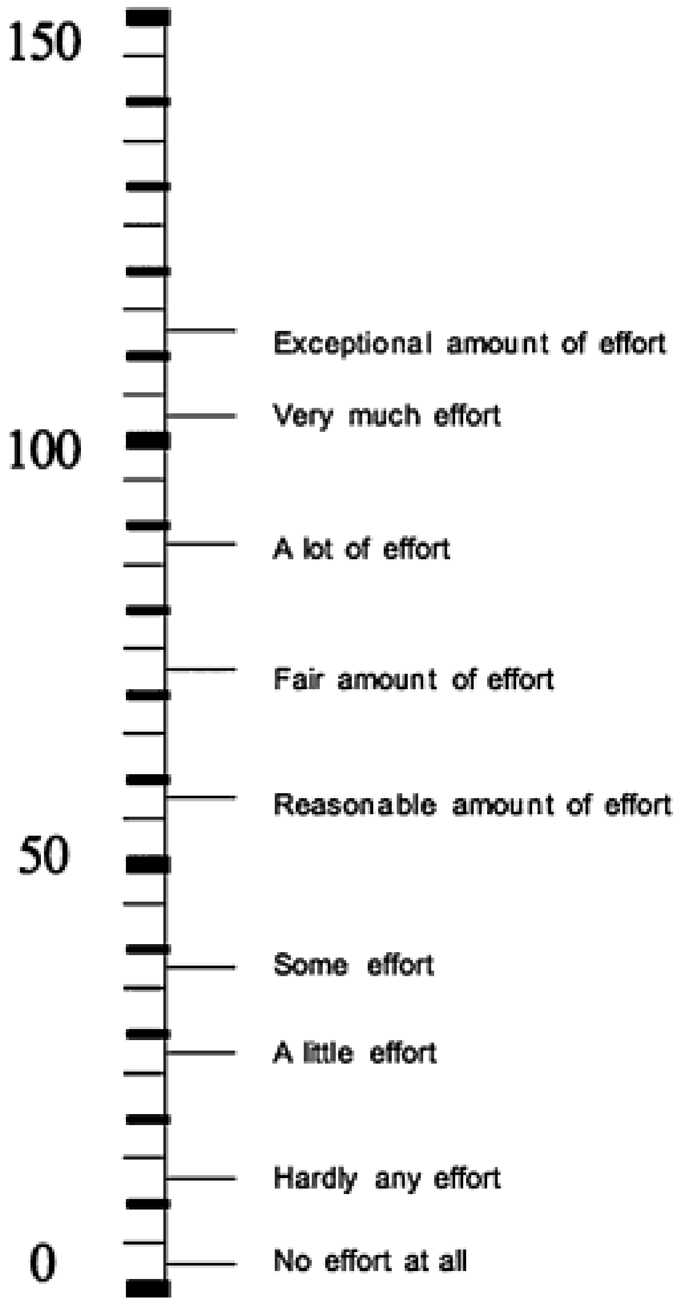
1) Self-reported (subjective). Study participants fill out questionnaires, surveys

Eg: Subjective Mental Effort Questionnaire (SMEQ) and the Local Experienced Discomfort (LED) scale

SMEQ

Subjective Mental Effort Questionnaire

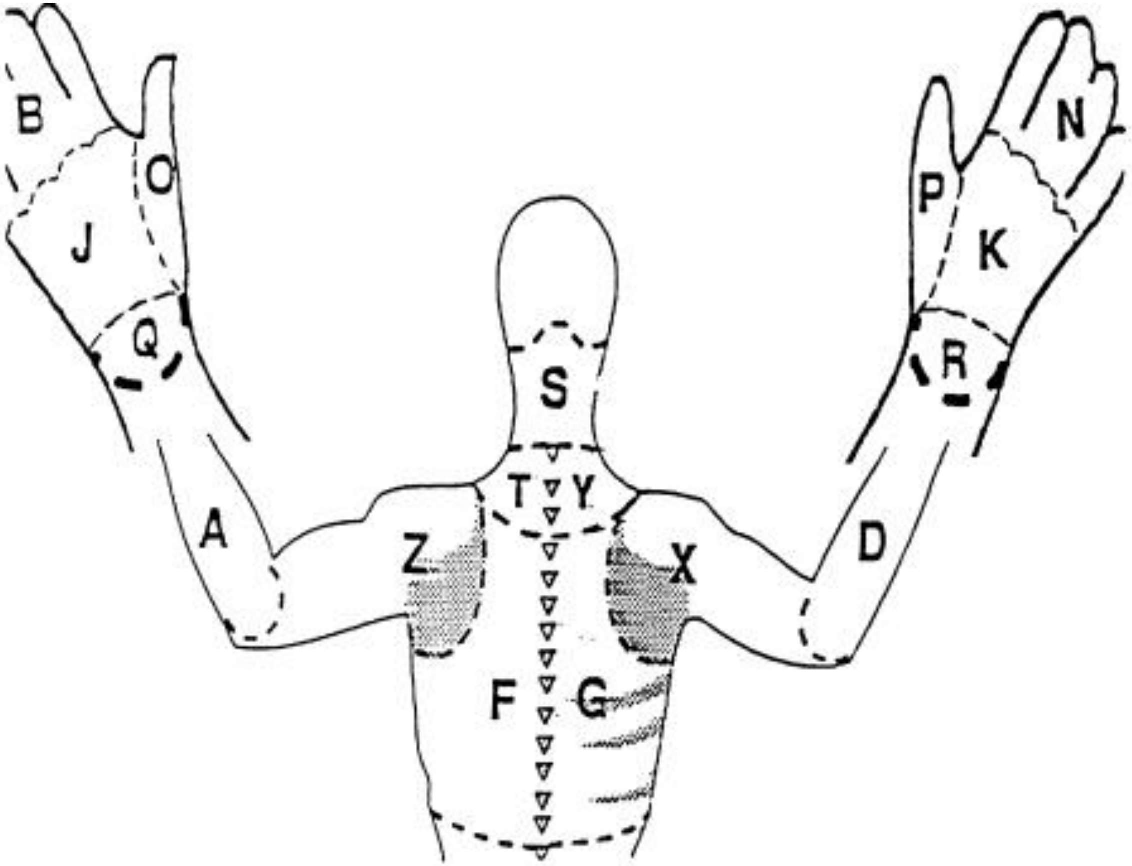
Olivier et al., Surgical Endoscopy 2009



LED

Local Experienced Discomfort

Olivier et al, Surgical endoscopy 2009



For each of the body parts indicated by the letters in the picture, please fill in a score as presented here below.

		Right side	Left side
	Maximum		
10	Extreme amount of complaints		
9		B ...	N ...
8		J ...	K ...
7	A lot of complaints	O ...	P...
6		Q ...	R ...
5		A ...	D ...
4	Quite a lot complaints	Z ...	X...
3		T ...	Y...
2	Some complaints	S ...	S ...
1		F...	G ...

Measurement methods

2) Measured with sensors (objective):

a) Motion analysis: video- manual analysis, optical tracking , EM tracking, Orientation sensor

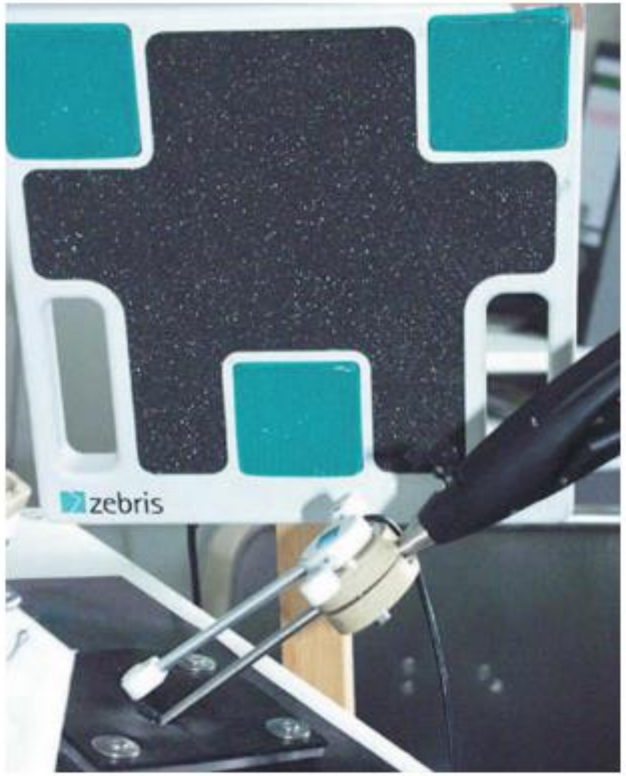
Optical motion systems capable of handling hundreds of markers-

Measure flexion/extension, abduction/adduction, internal/external rotation , CoM

Factors to consider: occlusion, interference, space requirements

Table 1. Motion Analysis Technologies in Surgical Ergonomics

Technology	User groups	Components
Orientation sensor	Berguer et al,[31] Smith et al,[32,54] Kondraske et al[73]	Solid-state 3-axis pitch, roll, and yaw sensor
Electromagnetic tracking	Huber et al,[33] Rasmus et al,[57] Dosis et al,[58,83] Ridgway et al,[75] Datta et al,[74] Mackay et al,[76] Bann et al,[77] Khan et al,[78] Moorthy et al,[79,81] Hernandez et al,[80] Munz et al,[82] Aggarwal et al,[84] Smith et al[85]	Electromagnetic field generator and receivers
Optical tracking	Emam et al,[35,36,38,47-49] Person et al,[56] van Veelen et al,[59] Lee et al,[72,88,89] Patil et al,[86] Gillette et al[87]	Computer-controlled video camera and retroreflective markers
Video analysis	van Veelen et al,[29,40] Matern et al,[30,90] Joice et al[45,62]	Video recording and observation



Ultrasound tracking
Zebris, Isny, Germany

b) EMG- Electro-myography

Muscle exertion causes change of the action potentials which can be measured just above the skin using electrodes

EMG data analysis relates muscle activation to outcome (force, torque, movement, fatigue level)

Three types of analysis:

1) Amplitude of EMG signal averaged over time

2) Percentage of Maximum Voluntary Contraction (% MVC)

3) Frequency analysis – task induced fatigue

c) Force plate Systems

Plates that measure Ground Reaction Force (GRF) through piezoelectric transducers or strain gauges

Can provide:

1) 3D resolution of force

2) 2D coordinates of Centre of Pressure

3) rotational moments about x, y and z axes

This system is good only for overall posture measurement

Assessment

Positives:

A thorough classification and description of tasks and measurement methods

Applicable to both tool and workspace integration ergonomics

Discusses advantages and limitations of the various methods

Has been used to evaluate robot assisted surgeries

Negatives:

Does not provide a scoring system that can give actionable advice

Paper 3: Rapid Entire Body Assessment (REBA)

Hignett, S., & Mcatamney, L. (2000). Rapid Entire Body Assessment (REBA). *Applied Ergonomics, 31*(2), 201 -205.

Postural analysis tool specifically developed for healthcare practitioners

Features of REBA:

1) Sensitivity to musculoskeletal risks in a variety of tasks
2) Segmentation of body and coding of segments
3) Scoring system for muscle activity caused by static, dynamic, rapid changing or unstable postures
4) Hand hold is given importance
5) Action level with indication of urgency
6) Only pen and paper required

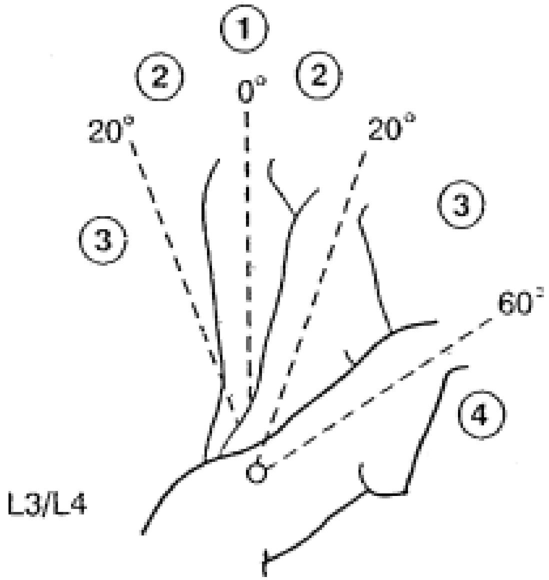
REBA scores

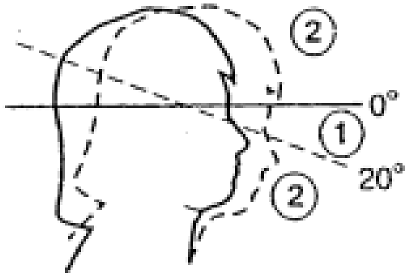
Trunk

Movement	Score	Change score:
Upright	1	+1 if twisting or side flexed
0°–20° flexion 0°–20° extension	2	
20°–60° flexion >20° extension	3	
>60° flexion	4	

Neck

Movement	Score	Change score:
0°–20° flexion	1	+1 if twisting or side flexed
>20° flexion or in extension	2	





Group A parts:

Leg
Neck
Trunk
- 60 posture combinations

Group B parts:

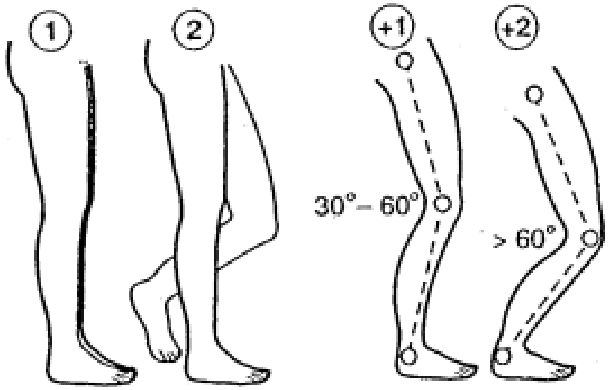
Upper arms
Lower arms
Wrists
-36 posture combinations

Group A+ B:
144 combinations

REBA scores

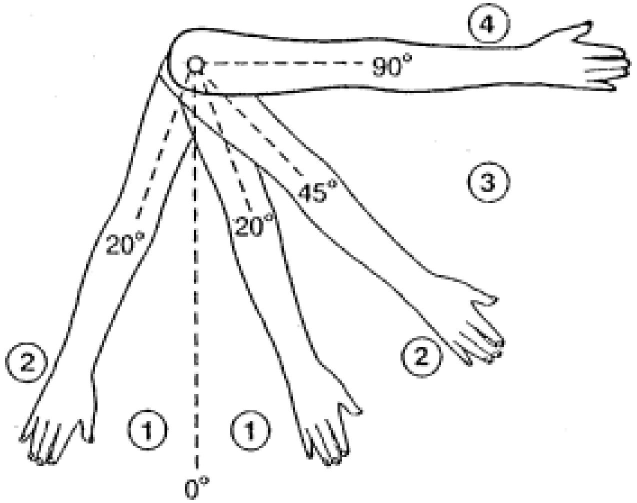
Legs

Position	Score	Change score:
Bilateral weight bearing, walking or sitting	1	+1 if knee(s) between 30° and 60° flexion
Unilateral weight bearing Feather weight bearing or an unstable posture	2	+2 if knee(s) are >60° flexion (n.b. Not for sitting)



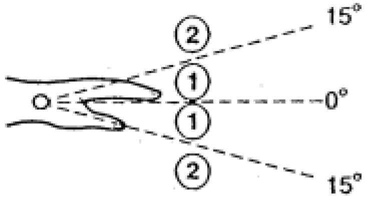
Upper arms

Position	Score	Change score:
20° extension to 20° flexion	1	+1 if arm is: • abducted • rotated
>20° extension 20°–45° flexion	2	+1 if shoulder is raised
45°–90° flexion	3	–1 if leaning, supporting weight of arm or if posture is gravity assisted
>90° flexion	4	



Wrists

Movement	Score	Change score:
0°–15° flexion/ extension	1	+1 if wrist is deviated or twisted
>15° flexion/ extension	2	



Example- physiotherapist with patient

Group A:
Trunk is flexed more than 60 degrees, side flex (4 +1)
Neck is extended (2)
Legs are both weight bearing and flexed more than 60 degrees (1 +2)
Load force < 5 kg (0)

Group B:
Upper arms flexed between 45 to 90 degrees, abducted, gravity assisted (3 + 1 -1)
Lower arm flexed less than 60 degrees (2)
Wrist 0 to 15 degrees (1)

Coupling: (1) not ideal hand-hold

A-B table and activity score

		Score B											
		1	2	3	4	5 ◆	6	7	8	9	10	11	12
Score A	1	1	1	1	2	3	3	4	5	6	7	7	7
	2	1	2	2	3	4	4	5	6	6	7	7	8
	3	2	3	3	3	4	5	6	7	7	8	8	8
	4	3	4	4	4	5	6	7	8	8	9	9	9
	5	4	4	4	5	6	7	8	8	9	9	9	9
	6	6	6	6	7	8	8	9	9	10	10	10	10
	7	7	7	7	8	9	9	9	10	10	11	11	11
	8 ◆	8	8	8	9	10	10	10	10	10	11	11	11
	9	9	9	9	10	10	10	11	11	11	12	12	12
	10	10	10	10	11	11	11	11	12	12	12	12	12
	11	11	11	11	11	12	12	12	12	12	12	12	12
	12	12	12	12	12	12	12	12	12	12	12	12	12

Activity score

• +1	• 1 or more body parts are static, e.g. held for longer than 1 min
• +1	• Repeated small range actions, e.g. repeated more than 4 times per minute (not including walking)
• +1	• Action causes rapid large range changes in postures or an unstable base

REBA action level

10 + 1 = 11

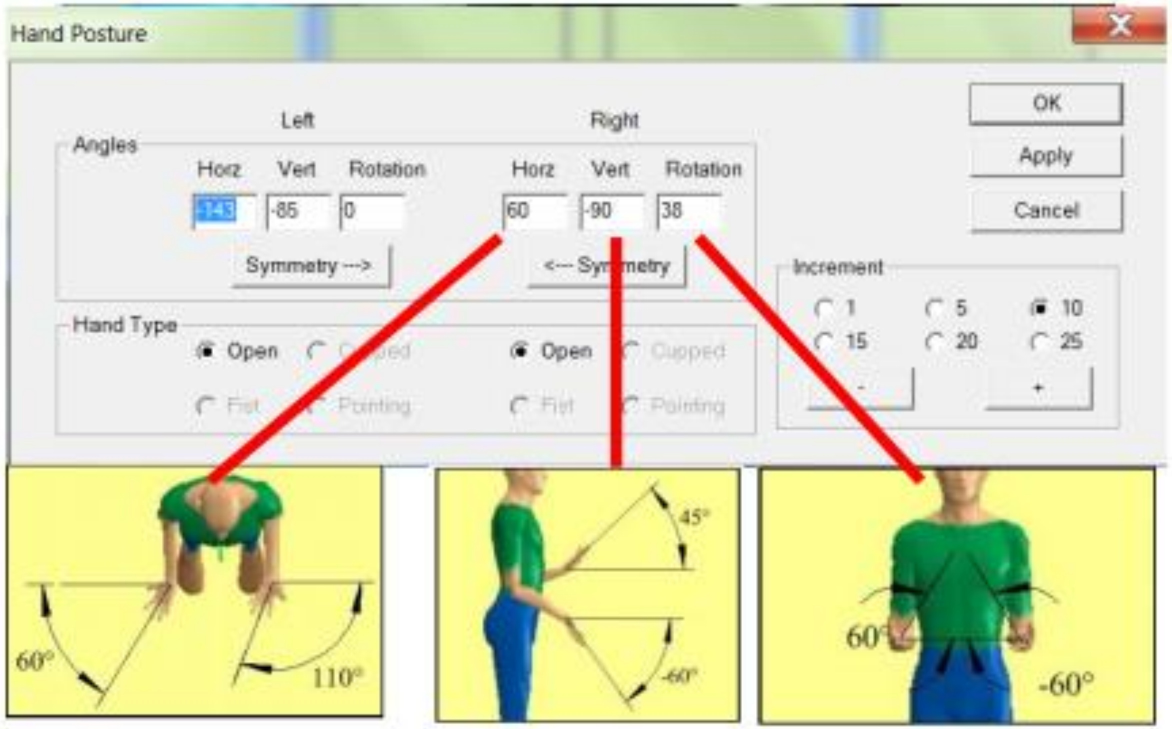
(A-B table+ action)

High risk task!

REBA action levels

Action level	REBA score	Risk level	Action (including further assessment)
0	1	Negligible	None necessary
1	2–3	Low	May be necessary
2	4–7	Medium	Necessary
3	8–10	High	Necessary soon
4	11–15	Very high	Necessary NOW

REBA software



Assessment

Positives:

REBA tool has been evaluated for over a decade and found to be quite accurate and popular

Easy to understand and use

Has been used to evaluate robotic assisted surgeries

Negatives:

Does not deal with fingertip forces

Conclusion

1) Papers together make comprehensive resource for ergonomic design and evaluation

2) Our surgical instrument is integrated with a robot, we may face unique challenges while trying to implement safe and effective instrument design

3) We do not aim to test the instruments with experienced surgeons, the knowledge of correct working posture can help in our self-evaluation.

Questions?