A BIOMECHANICAL AND KINESIOLOGICAL APPROACH IN THE TEACHING OF EFFICIENT SURGICAL SKILLS TO MEDICAL STUDENTS

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A competency-based surgery residents teaching and training program including a biomechanical and kinesiological approach was developed in order to improve procedural learning and mastery of invasive skills. Principles of biomechanics and kinesiology have been taught and applied to many aspects of surgical tasks, including instrument holding and manipulation, body positioning and posture, segments alignment. Results demonstrate more precise movements and more efficient performance of surgical tasks in residents participating in the program.

KEY WORDS : surgical skills, occupational biomechanics, teaching, movement efficiency

INTRODUCTION: Performance of invasive skills form an important part of residency training in surgery. The learning process is very often based mostly on theoretical knowledge accompanied with observation of surgeons at work and some form of instruction given to junior residents by senior residents (Mandel, Lentz & Goff, 2000; Rogers, Regehr, Gelula, Yeh, Howdieshell & Webb, 2000; Cauraugh, Martin & Komer-Martin, 1999; Martin, Vashisht, Frezza, Ferone, Lopez, Pahuja & Spence, 1998). The need for better training of residents has already been emphasized by many authors (Anastakis, Hamstra & Matsumoto, 2000). While Reznick (1993) "encouraged operative teachers to follow simple learning principles…" and to "… provide positive feedback on multiple procedural skills…" as part of residents' training, Cauraugh et al. (1999) have indicated that "perceptual-motor capabilities and experiences should be incorporated into the curriculum as more than a supplement to anatomical knowledge", in order for the residents to develop expertise in operative skills. In order to overcome many deficiencies in procedural knowledge (how to do) exhibited by surgery residents, the education curriculum and training experience should include opportunities for the residents to increase their ability to properly manipulate and control surgical instruments as well as some form of visual feedback on their procedural performance (Cauraugh et al., 1999). Moreover, visuo-spatial and visuo-motor abilities should be developed and practiced in such a way as to optimize surgical skills performance (Anastakis et al., 2000; Cauraugh et al., 1999)

Contribution of biomechanics and kinesiology: Biomechanics and Kinesiology can contribute in many ways to the general expertise of surgery residents, more specifically in the development of their procedural knowledge. A first contribution deals with the correctness of surgical movements and includes four phases : 1) the observation and biomechanical analysis of the surgical movements performed by the resident; 2) the comparison of the execution modes with biomechanical efficiency principles; 3) the proposition of appropriate corrections, using video-feedback and 4) a re-evaluation of the surgical task, after appropriate training and practice. Biomechanics and Kinesiology can also contribute to the sequencing of surgical movements for a particular surgery. The analysis and the breaking down of each movement sequence into precise steps will facilitate the mental representation of the individual movements to perform. Principles from occupational biomechanics can also be applied to the analysis of the resident's posture and to the optimisation of both body position and surgery table adjustments in order to allow for more precise and less fatiguing movements. Proper holding and manipulation of surgical instruments can also benefit from biomechanics. A proper holding technique will allow for more precision, a wider range of movement, better control on force and pressure and will induce less fatigue. Application of biomechanical principles will also provide better stabilization of the segment performing the surgical task. This is mostly achieved through the use of an intermediate support for the performing limb. Alignment of mechanical axes is

another biomechanical principle that should be taught and practiced in order to reduce fatigue of hand, wrist and forearm of the operating limb. Once proper holding techniques and manipulation skills are mastered, once segments are stabilized and mechanical axes aligned, then the resident can search for optimum surgical performance, while trying to adopt the postural attitude that will produce the least amount of muscular fatigue.

METHODS: Such a biomechanical and kinesiological approach was developed and incorporated into a competency-based training program for first year postdoctoral surgery residents at the University of Sherbrooke. Residents who were on campus formed the participants group, while those who were beginning their training in hospitals located in other cities served as controls. During the first ten (10) weeks of their residency, the program was offered once a week, for a period of four (4) consecutive hours, to the residents of the participants group. Each session aimed at developing competency in a specific surgical procedure to be performed on cadavers in the anatomy laboratory and included the following phases : 1) First, the surgical procedure was explained and described. 2) Then, each resident performed the surgical procedure on a cadaver, while being filmed with three (3) video cameras positioned above and each side of the cadaver. 3) Afterwards, residents were assigned to small groups who practiced the procedure on cadavers under the supervision of a surgeon as well as experts in biomechanics and kinesiology, who pointed out procedural errors and proposed more appropriate and less fatiguing techniques, while explaining underlying principles. 4) Then each resident was filmed again while performing on another cadaver. 5) During the following week, the videos were analysed at the biomechanics laboratory. 6) Feedback accompanied with pertinent video sequences was then given to the residents; inappropriate movements were pointed out and more appropriate techniques were proposed. Ways of optimising the procedural strategies were discussed and emphasized.

RESULTS: Continuous qualitative evaluation of residents competency by expert surgeons while performing surgical tasks both on cadavers and in the actual operating room situation revealed that participants 1) had better control of instruments, 2) exhibited more hand skill and precision while performing surgical tasks, 3) had more precise mental representation of the different steps involved in a particular surgery procedure, 4) took less time to perform specific surgical procedure, and 5) seemed less fatigued after long surgical tasks. A standardized battery of tests (OSCE) evaluating practical clinical skills was also administered to the participants and to the control groups after the program as well as three months later (Table 1).

Table 1 Performance of Residents on Practical Tests (OSCE)

	Participants (n=9)			Non-participants (n=5)		
	M		STD	M		STD
OSCE score : After the program	85.1 %*	±	6.0	50.5%	±	20.0
OSCE score 3 months after the program	92.9%*	±	5.7	64.6%	±	14.7

* $p < .01$ (Wilcoxon)

DISCUSSION AND CONCLUSION: Quantitative evaluation of surgical skill performances of residents both after the program and three (3) months later clearly indicate that participants

have developed a higher level of procedural knowledge and skills than non-participants and that this difference between the two groups persists during the following months of their residency training. Moreover, qualitative evaluation of residents performing surgical procedures has allowed evaluators to observe faster improvement of participants in many aspects of the surgical tasks, namely better holding technique and segments alignment, allowing for greater precision and force control, as well as less fatiguing postures. The main educational outcome of this program is a learning experience for the resident. It allows the resident to better visualize the execution of specific surgical movements and to address proper movement correction. Moreover, residents have shown a great interest in the program, mostly because of the active part they are taking in their learning process. This was particularly reflected in their desire for better understanding and wider application of biomechanical and kinesiological principles for the improvement of their surgical skills.

REFERENCES:

Anastakis, D.J., Hamstra, S.J. & Matsumoto, E.D. (2000). Visual-spatial abilities in surgical training. *American Journal of Surgery*, **179** (6), 469-471.

Cauraugh, J. H., Martin, M. & Komer-Martin, K. (1999). Modeling surgical expertise for motor skill acquisition. *American Journal of Surgery,* **177**, 331-336.

Mandel, L. P., Lentz, G. M. & Goff, B. A. (2000). Teaching and evaluating surgical skills. *Obstetrics and Gynecology,* **95** (5), 783-785.

Martin, M., Vashisht, B., Frezza, E., Ferone, T., Lopez, B., Pahuja, M. & Spence, R.K. (1998). Competency-based instruction in critical invasive skills improves both resident performance and patient safety. *Surgery*, **124** (2), 313-317.

Reznick, R.K. (1993). Teaching and testing technical skills. *American Journal of Surgery*, **165**, 358-361.

Rogers, D.A., Regehr, G., Gelula, M., Yeh, K.A., Howdieshell, T.R. & Webb, W. (2000). Peer teaching and computer-assisted learning: An effective combination for surgical skill training? *Journal of Surgical Research*, **92** (1) 53-55.