

## Supplementary material I

### *Selected influences on surgeons' tremor*

Factors that may reduce tremor during surgery include the following:

Mechanical factors:

- adjustment of instrument and finger configurations [19];
- use of passive orthotic supports [20, 26–29] [*cf.* 30]; and
- use of active mechanical compensation [12, 31–33].

Lifestyle factors:

- avoidance of caffeine intake prior to surgery [29] [*cf.* 34] [*contra* 1];
- avoidance of exercise prior to surgery [1, 10, 20];
- avoidance of fatigue [19] [see also 35]; and
- use of beta-blockers [20, 29, 34] [*contra* 30].

### *Selected influences on physiological tremor*

Factors that enhance physiological tremor include fatigue, anxiety, cognitive load, hyperthyroidism, warmth, and various agents (*e.g.*  $\beta$ -agonists, caffeine) [4, 15, 20, 21, 36–39]. Diurnal variation has also been reported [40, 41].

### References for Supplementary material I

- [1] D. Mürbe, K.-B. Hüttenbrink, T. Zahnert, U. Vogel, M. Tassabehji, E. Kuhlisch et al. Tremor in otosurgery: influence of physical strain on hand steadiness. *Otol Neurotol* 2001; 22:672–77.
- [4] R. J. Elble. Tremor: clinical features, pathophysiology, and treatment. *Neurol Clin* 2009; 27:679–95.
- [10] P. A. Hsu and B. C. Cooley. Effect of exercise on microsurgical hand tremor. *Microsurgery* 2003; 23:323–27.
- [12] R. A. MacLachlan, B. C. Becker, C. J. Tabarés, G. W. Podnar, L. A. Lobes, Jr. and C. N. Riviere. Micron: an actively stabilized handheld tool for microsurgery. *IEEE Transactions on Robotics* 2012; 28:195–212.
- [15] G. Deuschl and A. Fasano. Chapter 29 — Essential tremor and other tremors. In: A. H. V. Schapira, A. E. T. Lang and S. Fahn (eds). *Movement Disorders 4*. Philadelphia, U.S.A.: Saunders/Elsevier, 2010:506–57.
- [19] R. L. Ferguson and K. Jobe. A quiet hand for microneurosurgery: twiddle your thumb. *J Neurosurg* 2004; 101:541–44.
- [20] M. Patkin. Ergonomics applied to the practice of microsurgery. *Aust N Z J Surg* 1977; 47:320–29.
- [21] W. Growdon, J. Ghika, J. Henderson, G. Van Melle, F. Regli, J. Bogousslavsky et al. Effects of proximal and distal muscles' groups contraction and mental stress on the amplitude and frequency of physiological finger tremor. An accelerometric study. *Electromyogr Clin Neurophysiol* 2000; 40:295–303.
- [26] A. Csókay. A novel microsurgical technique reduces hand tremor in the course of lateral suboccipital approach. *Surgical Neurology* 2007; 67:392–93.
- [27] J. I. Ausman. Commentary on 'A novel microsurgical technique reduces hand tremor in the course of lateral suboccipital approach'. *Surgical Neurology* 2007; 67:393–94.
- [28] C. J. Coulson, P. S. Slack and X. Ma. The effect of supporting a surgeon's wrist on their hand tremor. *Microsurgery* 2010; 30:565–68.
- [29] R. W. Arnold, D. T. Springer, W. K. Engel and E. M. Helveston. The effect of wrist rest, caffeine, and oral timolol on the hand steadiness of ophthalmologists. *Ann Ophthalmol* 1993; 25:250–53.
- [30] J. D. Lubahn, B. G. Dickson and T. E. Cooney. Effect of Timolol vs. a postural orthotic on hand tremor during microsurgery. *Microsurgery* 2002; 22:273–76.
- [31] S. Yang, R. A. MacLachlan and C. N. Riviere. Manipulator design and operation of a six-degree-of-freedom handheld tremor-canceling microsurgical instrument. *IEEE/ASME Transactions on Mechatronics* 2015; 20:761–72.

- [32] Y. N. Aye, S. Zhao, C. Y. Shee and W. T. Ang. Vision aided active error canceling in handheld microsurgical instrument. *Procedia Engineering* 2012; 41:729–36.
- [33] C. Payne and G.-Z. Yang. Hand-held medical robots. *Ann Biomed Eng* 2014; 42:1594–605.
- [34] M. U. Humayun, R. S. Rader, D. J. Pieramici, C. C. Awh and E. de Juan, Jr. Quantitative measurement of the effects of caffeine and propranolol on surgeon hand tremor. *Arch Ophthalmol* 1997; 115:371–74.
- [35] P. S. Slack, C. J. Coulson, X. Ma, P. Pracy, S. Parmar and K. Webster. The effect of operating time on surgeon's hand tremor. *Eur Arch Otorhinolaryngol* 2009; 266:137–41.
- [36] A. Dalvi and A. Premkumar. Tremor: etiology, phenomenology, and clinical features. *Disease-a-Month* 2011; 57:109–26.
- [37] V. Hömberg, K. Reiners, H. Hefter and H. J. Freund. The muscle activity spectrum: spectral analysis of muscle force as an estimator of overall motor unit activity. *Electroencephalogr Clin Neurophysiol* 1986; 63:209–22.
- [38] M. Lakie, E. G. Walsh, L. A. Arblaster, F. Villagra and R. C. Roberts. Limb temperature and human tremors. *Journal of Neurology, Neurosurgery & Psychiatry* 1994; 57:35–42.
- [39] C. D. Marsden, J. C. Meadows, G. W. Lange and R. S. Watson. Variations in human physiological finger tremor, with particular reference to changes with age. *Electroencephalogr Clin Neurophysiol* 1969; 27:169–78.
- [40] J. J. van Hilten, J. G. van Dijk, R. J. Dunnewold, E. A. van der Velde, B. Kemp, P. van Brummelen et al. Diurnal variation of essential and physiological tremor. *Journal of Neurology, Neurosurgery & Psychiatry* 1991; 54:516–19.
- [41] P. J. Tyrer and A. J. Bond. Diurnal variation in physiological tremor. *Electroencephalogr Clin Neurophysiol* 1974; 37:35–40.