Intracranial pressure

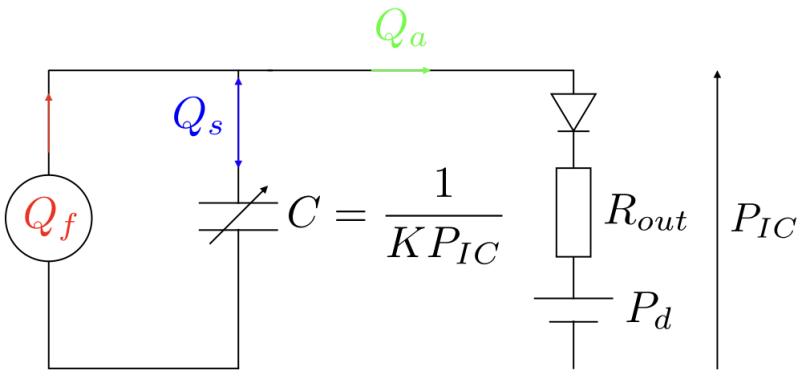

FIGURE 1 – Drawing of the cerebrospinal fluid system described as an electrical analogy.

$$C = \frac{1}{K P_{IC}} \tag{1}$$

Conservation of mass requires:

$$Q_f = Q_a + Q_s \tag{2}$$

$$Q_a = \frac{P_{IC} - P_d}{R_{out}} \tag{3}$$

$$P_d = P_r - Q_f \; R_{out} \tag{4}$$

where P_r is the resting pressure, P_d is the dural venous pressure.

$$\frac{\mathrm{d}P_{IC}}{\mathrm{d}t} = K \; P_{IC} \; Q_s = K \; P_{IC} \; (Q_f - Q_a) \tag{5}$$

Substituting Eq. (3) in (5):

$$\frac{\mathrm{d}P_{IC}}{\mathrm{d}t} = K \; P_{IC} \; Q_f - K \; P_{IC} \frac{P_{IC} - P_d}{R_{out}} \tag{6}$$

Analytic solution for Eq. (6) is the following:

$$P_{IC}(t) = \frac{P_p e^{\frac{KtP_r}{R_{out}}}}{1 + \frac{P_p}{P_r}\left(e^{\frac{KtP_r}{R_{out}}} - 1\right)} \tag{7}$$

Discretizing with an explicit Euler scheme leads to:

$$P_{IC}^{n+1} = P_{IC}^{n} + \Delta t \; K \; P_{IC}^{n} \left(Q_f^n - \frac{P_{IC}^n - P_d}{R_{out}} \right) \tag{8}$$

Q_f	0.36 mL/min
K	0.5 mL
R_{out}	7.5 mmHg / (mL/min)
P_r	30 mmHg
$P_{IC}(0)$	8 mmHg

TABLE 1 – Parameters of the model

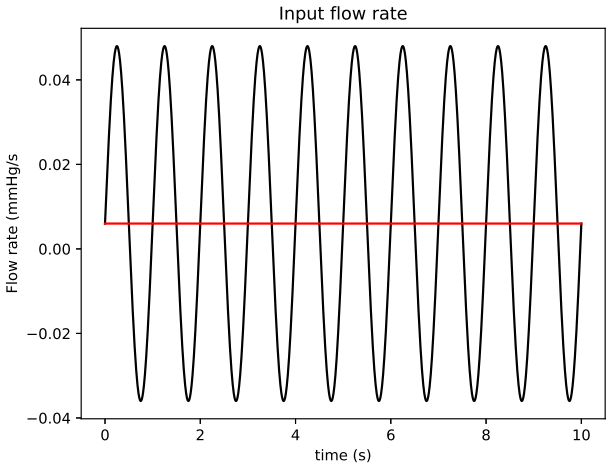

FIGURE 2 – Pulse input Q_f (in black) and constant input flow Q_f (in red) as a function of time.

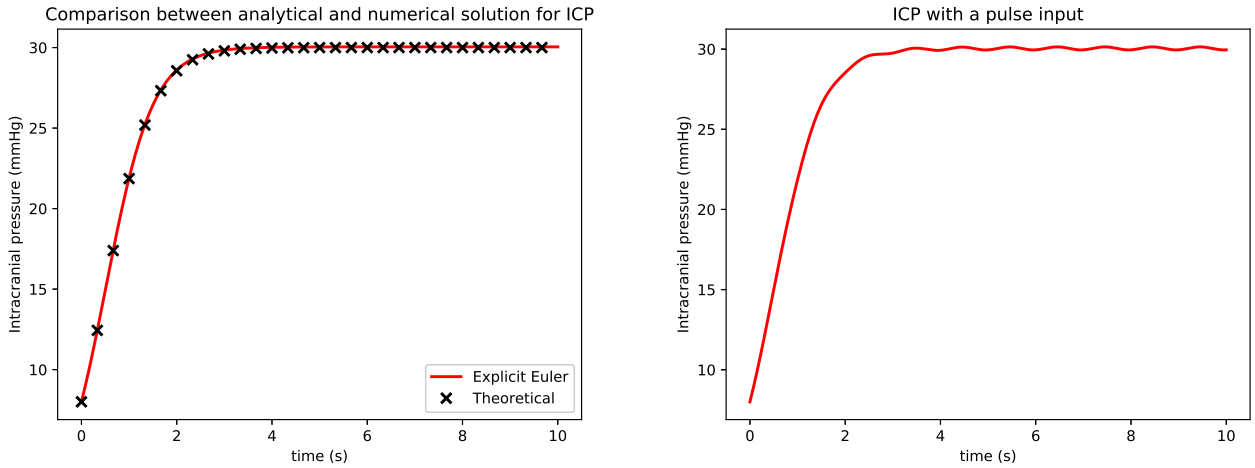

FIGURE 3 – Intracranial pressure (in mmHg) as a function of time (in s) for two different Q_f. Left: comparison between analytical solution (7) and numerical solution of Eq. (8) with a constant Q_f. Right: numerical solution of Eq. (8) for intracranial pressure with a pulse Q_f.

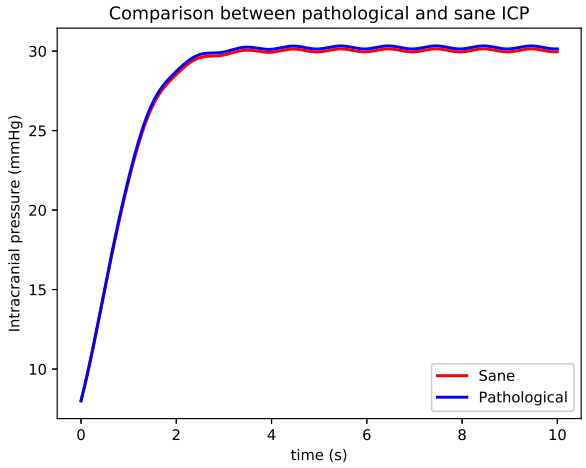

FIGURE 4 – Intracranial pressure (in mmHg) for sane (red) and pathological (blue)

References

[1] A. Eklund, P. Smielewski, I. Chambers, N. Alperin, J. Malm, M. Czosnyka, and A. Marmarou. Assessment of cerebrospinal fluid outflow resistance. *Med Bio Eng Comput*, 2007.