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Biomechanics – Pulling out of infusion hoses

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Abstract. The scope of this paper is to determinate critical tearing force. The original measurements were performed for cannula and its securing fixation in patient's body (i.e. applications in medico-chirurgical branches). Data (i.e. pull out or tearing forces) acquired from this experiment may later be used in designing of a device for automatic winding of infusion tubes etc.

Introduction

This article is focused on biomechanics and medical science (i.e. application of infusion hoses for patients in a hospital - cannula and its securing fixation; see Fig. 1). In our case, infusion hoses are placed on patient's forearm. A medical term cannula is a tube that can be inserted into the body, often for the delivery or removal of fluid or for the gathering of data. The anatomical interaction between mechanical circulatory or respiratory support and the patient is achieved by specially designed cannulae. For more information see references [1] to [5].

Fig. 1: Intravenous cannulation - (a) Porcine skin, (b) human skin

During a treatment in a hospital etc., if the cannula is pulled (ripped, torn) out from a vein of a patient, by accident or intentionally, it may lead to serious consequences or even death if not checked in time. In order to ensure the safety of patients and make the patients have a good rest during liquid infusion, the cannulae and infusion hoses must be correctly proposed and designed.

The goal of this paper is to determine the minimum force needed for a patient to pull on an infusion tube with cannula at its end to tear it out from vein. And also, to specify force to be pulling on an infusion tube from automatic winding device to keep the tube outstretched, but not to pull too strong.

There is a lack of information about cases of patients tearing cannulas out of their skin. Therefore, it is important to do measurements in this area.

Description of Experiments

First idea for experiment was to use porcine body with skin. However, the problem was that the porcine skin, even after proper preparation was still too oily, therefore the securing tapes did not hold, and cannulas themselves were quite easy to pull out; see Fig. 1(a).

The main element holding cannulas in place are the securing tapes, or in some cases the cannulas can be sewn onto patient's skin, but this was not the case of this experiment.

For more realistic approach, the experimental measurements were done several times in several anatomic directions on right human forearm. For each of seven directions were done two measurements. Directions are shown in Fig. 2. The cannulas were put on human skin and taped in place, see Fig. 1(b). The measurements on humans were performed without inserted cannulae (i.e. infusion hoses were only taped – no intravenous cannulation).

The original measurements of pulling forces were based on general anatomical directions of infusion hoses with cannulae similar to patients with infusions in a hospital; see Fig. 2 and Tab. 1.

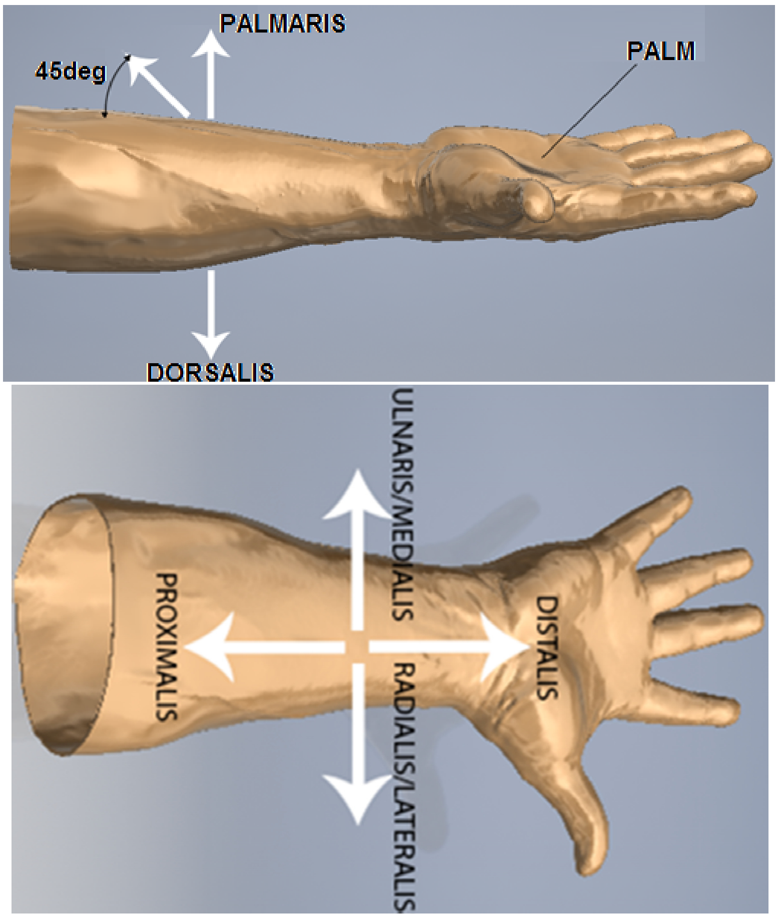

Fig. 2: Anatomical directions applied in measurements of pull out forces (right hand)

Table 1: Anatomical directions and measured data

Pull out Force		
Direction of Tensile Force, see Fig. 2	**Min. & Max. Tensile Force [N]**	**Average [N]**
Palmaris	19.12; 29.50	**24.31**
45 deg	31.87; 34.98	**33.43**
Distalis	21.52; 22.47	**22.00**
Radialis/Lateralis	35.47; 48.46	**41.97**
Ulnaris/Medialis	39.52; 23.51	**31.52**
Proximalis	50.39; 53.30	**51.85**
Dorsalis	34.84; 45.92	**40.38**
Maximum	53.30	**51.85**
Minimum	19.12	**22.00**
Median	34.91	**33.43**
Average	35.06	**35.06**

Measured by force transducer (load cell) HBM, type S2M/100N. In this picture, the direction of tensile force is 45 deg)

To measure the tensile force, the S2M/100N load cell (force transducer) developed by HBM was used. This load cell is capable of measuring forces up to 100 N, which was quite enough range for this experiment.

The measurements were performed at VSB – Technical University of Ostrava (Faculty of Mechanical Engineering, Department of Applied mechanics) in cooperation with University Hospital in Ostrava & University of Ostrava.

Results

Some result diagrams; see Fig. 3, 4 and Tab. 1, show dependencies of force on time, until the cannula is torn out or infusion tube is detached.

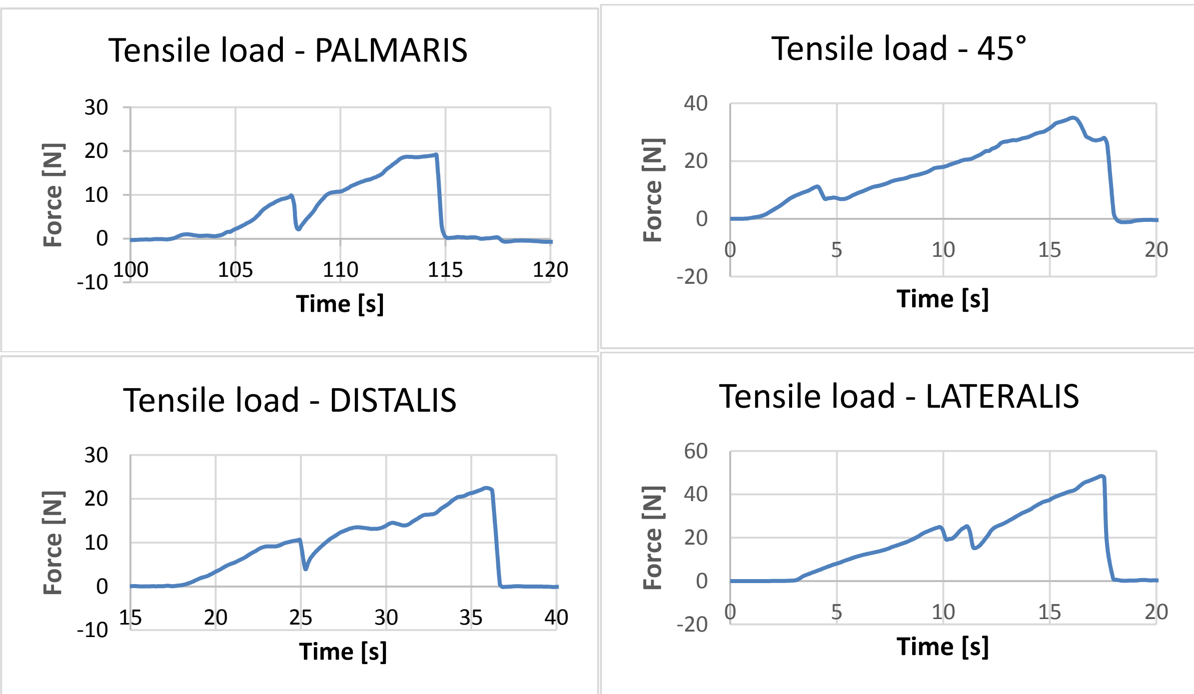

Fig. 3: Examples of pull out force measurement (a) Palmaris direction, (b) Under 45 deg. direction, (c) Distalis direction, (d) Lateralis direction

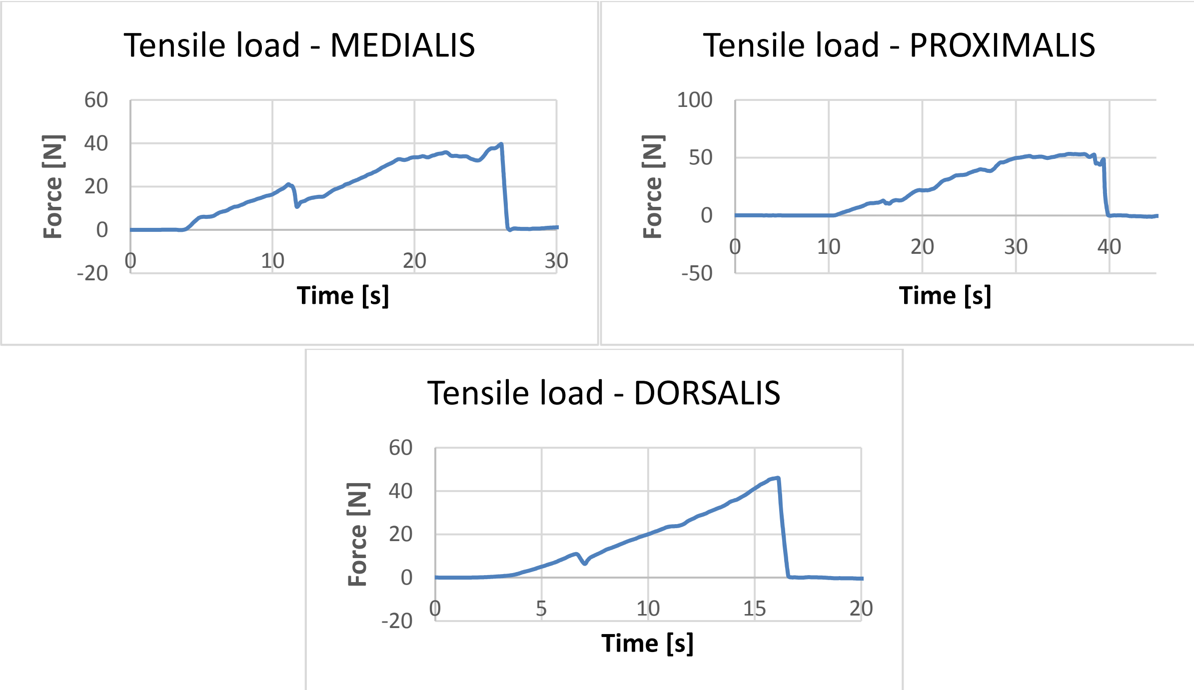

Fig. 4: Examples of pull out force measurement (a) Medialis direction, (f) Proximalis direction, (g) Dorsalis direction

Hence, the safe force (safety factor $k_S = 5$) to be used in auto winding device for hoses is

$$F = \frac{F_{AVERAGE}}{k_S} = \frac{35.06}{5} = 7\ \mathrm{N}. \tag{1}$$

For more information see [1] and [2].

Data acquired from this experiment will be used in designing of a device for automatic winding of infusion hoses.

Conclusions

From measured data; see Tab. 1 and Fig. 3, 4, the minimal & maximal tensile (torn out or pulling out) force can be determined (19.12 N & 51.85 N).

This result can be affected by the fact, that the measurements were done using the same tape without changing it for every measurement. However, the measurements are reliable and sufficient enough. The tapes (i.e. taped cannulae) held well enough in whole experiments.

The acquired results fill the information gap about this problem and can be applied in engineering design and improvement of safe medical treatment.

Acknowledgement

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