Integrated microcapillary system for microfluidic parasite analysis

András J. Laki,[a,c] Kristóf Iván,[a] Péter Fürjes[b] and Pierluigi Civera[c]

[a] Faculty of Information Technology, Pázmány Péter Catholic University, Budapest, Hungary
[b] MEMS Laboratory, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Budapest, Hungary
[c] Department of Electronics and Telecommunications, Polytechnic University of Turin, Turin, Italy

Abstract

We present the use of a simple microfluidic technique to detect living parasites from veterinarian blood using a monolithic polydimethylsiloxane (PDMS) structure. Several intravenous parasitosis can be observed by this developed microcapillary system such as dirofilariasis or Lyme disease.

A special flow-through separator structure has been implemented within this microfluidic device, which contains a cylindrical Active Zone, where the microfilariae or other few micron-size parasitic infections remain trapped. The center region is partially surrounded by rectangular cross-section shaped microcapillaries. The developed test can be optimized for a specific nematode or parasite by adjusting the capillary width.

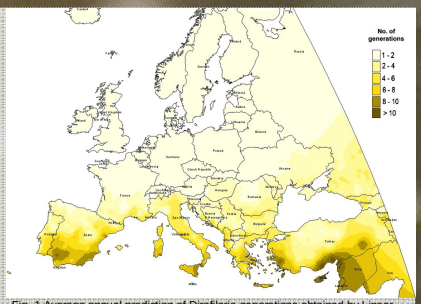


Fig. 1 Average annual prediction of Dirofilaria generations obtained by Linear Kriging interpolation. [1]

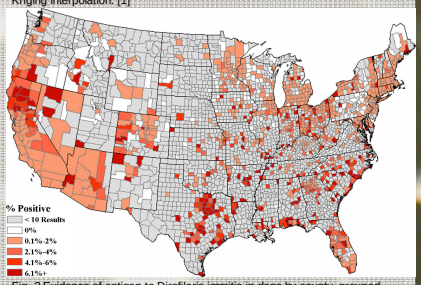


Fig. 2 Evidence of antigen to Dirofilaria immitis in dogs by county, grouped according to percent positive tests. [2]

Dirofilariasis

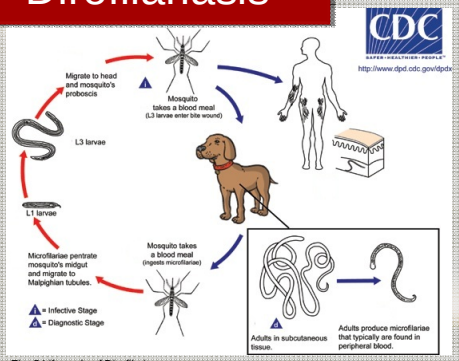
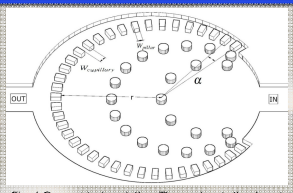


Fig. 3 Life cycle of Dirofilaria repens

The following diagnostic methods have been developed to register the existence of intravenous nematodes or to determine its volumetric population: fresh blood smear, modified Knott test, filter test, histochemical stain based test, enzyme-linked immunosorbent Assay (ELISA), immuno-chromatographic tests, antibody tests and polymerase chain reaction (PCR) based methods.

Principles of operation



$$\sin\frac{\alpha}{2} = \frac{W_{pillar} + W_{capillary}}{2r}$$

$$W_{capillary} = 2r\sin\frac{\alpha}{2} - W_{pillar}$$

$$\alpha = 2\sin^{-1}\left[\frac{W_{pillar} + W_{capillary}}{2r}\right]$$

Fig. 4 Geometric description. The angle α is the descriptor of structural repetition of the microcapillaries, r is the radius of the active zone, W_{pillar} is the width of the pillars, $W_{capillary}$ is the width of the capillary channels

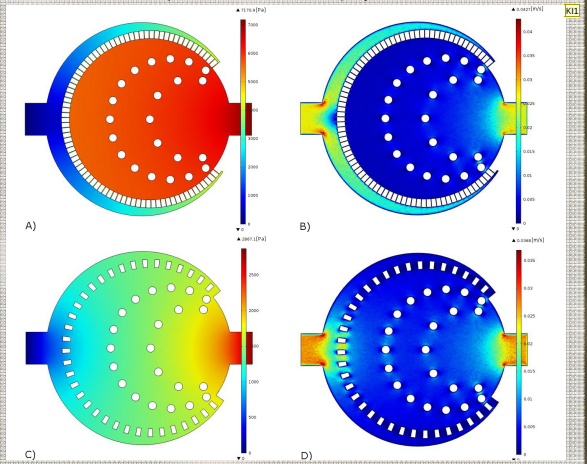


Fig. 5 Pressure and velocity profiles at same initial conditions ($v_{inlet} = 0.02\ m/s$) A) Pressure profile inside the thinnest capillary system ($\alpha = 3.4°$), where pressure drop is 7190 Pa. B) Velocity profile ($\alpha = 3.4°$), where $v_{max} = 0.042\ m/s$. C) Pressure profile inside the thickest capillary system ($\alpha = 8°$), where pressure drop is 2878 Pa. D) Velocity profile ($\alpha = 8°$), where $v_{max} = 0.0382\ m/s$.

Pressure drop

The pressure drop is a critical physical parameter of a filter structure. If the pressure is significant the trapped flexible particles can be squeezed through small capillaries while using and abnormal pressure the filter can be destroyed. The decreasing value of $W_{capillary}$ increases the pressure drop within the device. Cut off pressure has been set to 50 kPa.

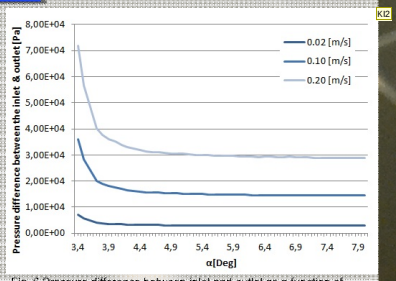


Fig. 6 Pressure difference between inlet and outlet as a function of angle α at fix inlet velocities ($0.02\ m/s, 0.1\ m/s, 0.2\ m/s$)

Conclusion & outlook

Pressure and velocity profiles have been calculated to predict the pressure drop to secure the efficiency of the developed device. We have successfully shown how intravenous nematodes can be detected using the developed flow-thought nematode filter. 48 different microfluidic devices have been designed, fabricated and tested to uncover dirofilariasis from veterinarian blood samples.

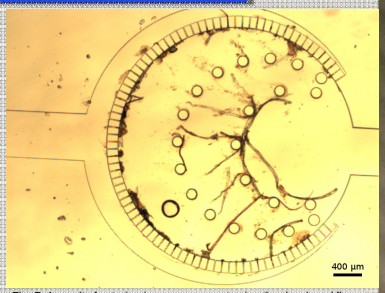


Fig. 7. A result of veterinarian measurement using the developed flow-thought nematode filter

Acknowledgment

We would like to thank Éva Fok and Olga Jacsó for the biological samples. We acknowledge Zoltán Fekete and Danilo Demarchi for their kind help. The support of grants TÁMOP-4.2.1.B-11/2/KMR-2011-0002 and TÁMOP-4.2.2/B-10/1-2010-0014 is gratefully acknowledged.

References

[1] C. Genchi et al. "Guideline for the laboratory diagnosis of canine and feline dirofilaria infections," Mappe Parassitologiche, pp. 139–144, Feb. 2007.
[2] D. Bowman et al., "Prevalence and geographic distribution of Dirofilaria immitis…" *Vet. Parasitol.*, vol. 160, no. 1–2, pp. 138–148, Mar. 2009.

Slide 1

KI1 A fig. 5 az 3D modell eredménye? azokat esetleg lehetne 3Ds modellből ábrázolni, döntve? streamline?
Kristóf Iván, 5/20/2013

KI2 Fig. 6 ábrát ÚJRA, "8,00E+04" nem jó tengelyfelirat!!! (esetleg legyen [kPa] a mértékegység, akkor 80 ig megy a tengely, legyen egy cutoff, ami a biztonságos értéket adja meg PDMS eszközöknél, mondjuk 50 kPa??? vízszintes piros vonal?
Kristóf Iván, 5/20/2013