Real-time Visual Analysis of Microvascular Blood Flow for Critical Care

Chao Liu * Hernando Gomez † Srinivasa Narasimhan * Artur Dubrawski *
Michael R. Pinsky † Brian Zuckerbraun †

1. Blood flow velocity distributions for all pigs

In the paper we have shown the blood flow velocity distributions for 5 pigs in Fig. 7. In this section we show the blood flow velocity distributions for all of the 18 pigs in our critical care experiment in Fig. 1 and Fig. 2. From the point of view of current knowledge of physiology of the observed processes, as the blood pressure decreases due to bleeding, a general reduction in blood flow velocity would be manifest by a shift of the distribution of velocities across vessels towards lower values. On the other hand, one would expect that if resuscitation efforts were successful, that microcirculatory blood flow return to baseline values.

In the experiment, some of the subjects (pigs 42, 55, 57, and 63) experienced episodes of profound cardiorespiratory insufficiency before reaching the last stage of the experiment (AfterHextend), which substantially changed their observed behavior. Also, some of the subjects were apparently less responsive to Hextend therapy during resuscitation as their blood flow velocity did not increase right after infusion.

2. Performance of the vessel skeleton extraction method

To evaluate the performance of the vessel extraction method used in our paper, we manually segmented vessels in the microcirculatory videos and compared the result with the estimated vessel skeletons. In Fig. 3 we show three such comparisons. The averaged recall and false detection rates are 87.90% and 0.65% respectively. Please note that neither of the methods being compared is guaranteed to provide the ground truth. The comparison metrics aim to reflect the extend of correspondence between the results of the laborious manual and fully automated process of segmentation.

3. Estimate the dominant orientation

Let $w(f_x, f_y)$ be the magnitude of the Fourier Transform, we want to find the optimal angle θ, the angle spanned by l and the y-axis, that minimizes the inertia:

$$E = \iint \left(r(f_x, f_y; \theta)\right)^2 w(f_x, f_y) df_x df_y \tag{1}$$

where $r(f_x, f_y; \theta)$ is the vertical distance from (f_x, f_y) to l; $w(f_x, f_y)$ is the magnitude of the Fourier Transform of the EPI image. It can be shown that the direction vector $\left(\sin(\theta^*), \cos(\theta^*)\right)^T$ for the optimal θ^* is the eigenvector with the smaller eigenvalue of the matrix:

$$M = \begin{bmatrix} \iint f_x^2 w(f_x, f_y) df_x df_y & \iint f_x f_y w(f_x, f_y) df_x df_y \\ \iint f_x f_y w(f_x, f_y) df_x df_y & \iint f_y^2 w(f_x, f_y) df_x df_y \end{bmatrix} \tag{2}$$

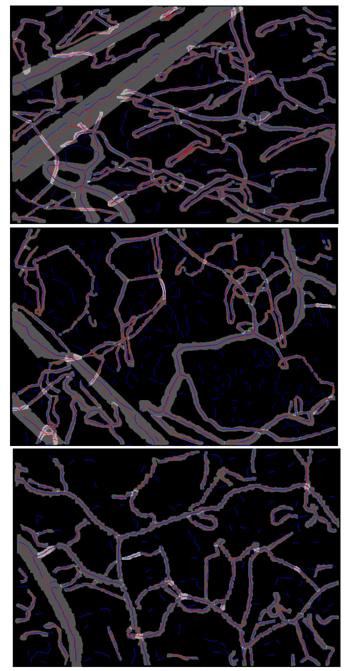

Figure 3: Three examples of comparisons between the automatically detected vessel skeletons (blue) and the manually marked vessel segments (shown in gray with bright parts when they overlap). Manually identified skeletons are shown in red. Best viewed when zoomed in.

*Carnegie Mellon University, The Robotics Institute. Email:{chao.liu, srinivas, awd}@cs.cmu.edu

†University of Pittsburgh, School of Medicine. Email:{gomezh, pinskymr, zuckerbraunbs}@upmc.edu

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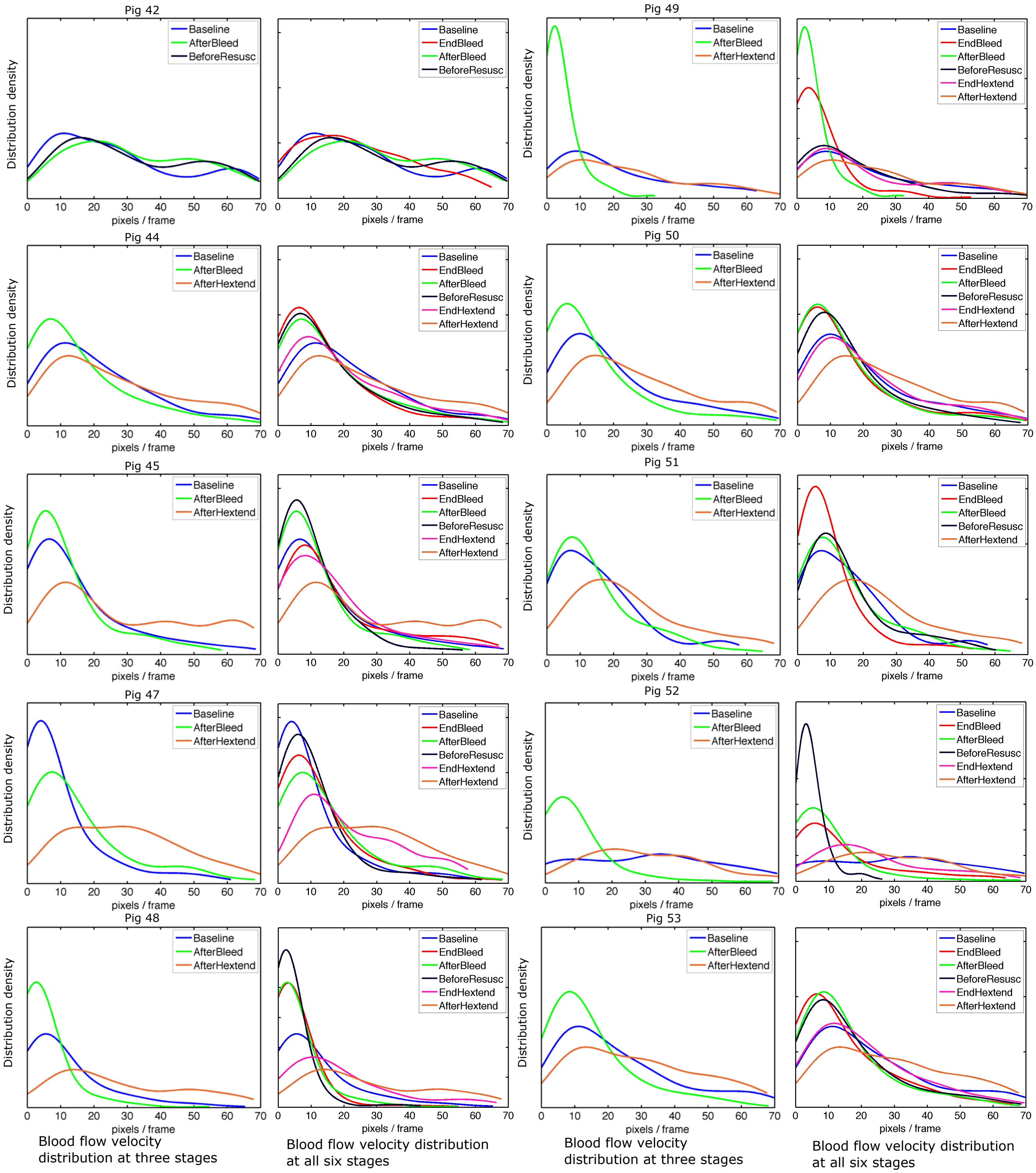

Figure 1: The estimated blood flow velocity distributions for pigs at different stages of the experiment. For each plot, the x-axis is the blood flow velocity, (pixels per frame); the y-axis is the distribution density of vessels with corresponding flow velocity. (a) The blood flow velocity distributions at three key stages: Baseline, end of bleed, and right after resuscitation. (b) The blood flow velocity distributions for all six stages. Annotations for stages: Baseline (blue) - right before the bleeding procedure; EndBleed (red) - end of bleed; Afterbleed (green) - 60 minutes after EndBleed; BeforeResusc (black) - Before resuscitation, 90 minutes after EndBleed, before the resuscitation procedure; EndHextend (purple) - end of resuscitation procedure; AfterHextend (yellow) - 120 minutes after EndHextend. The blood flow velocity decreases after the onset of bleeding.

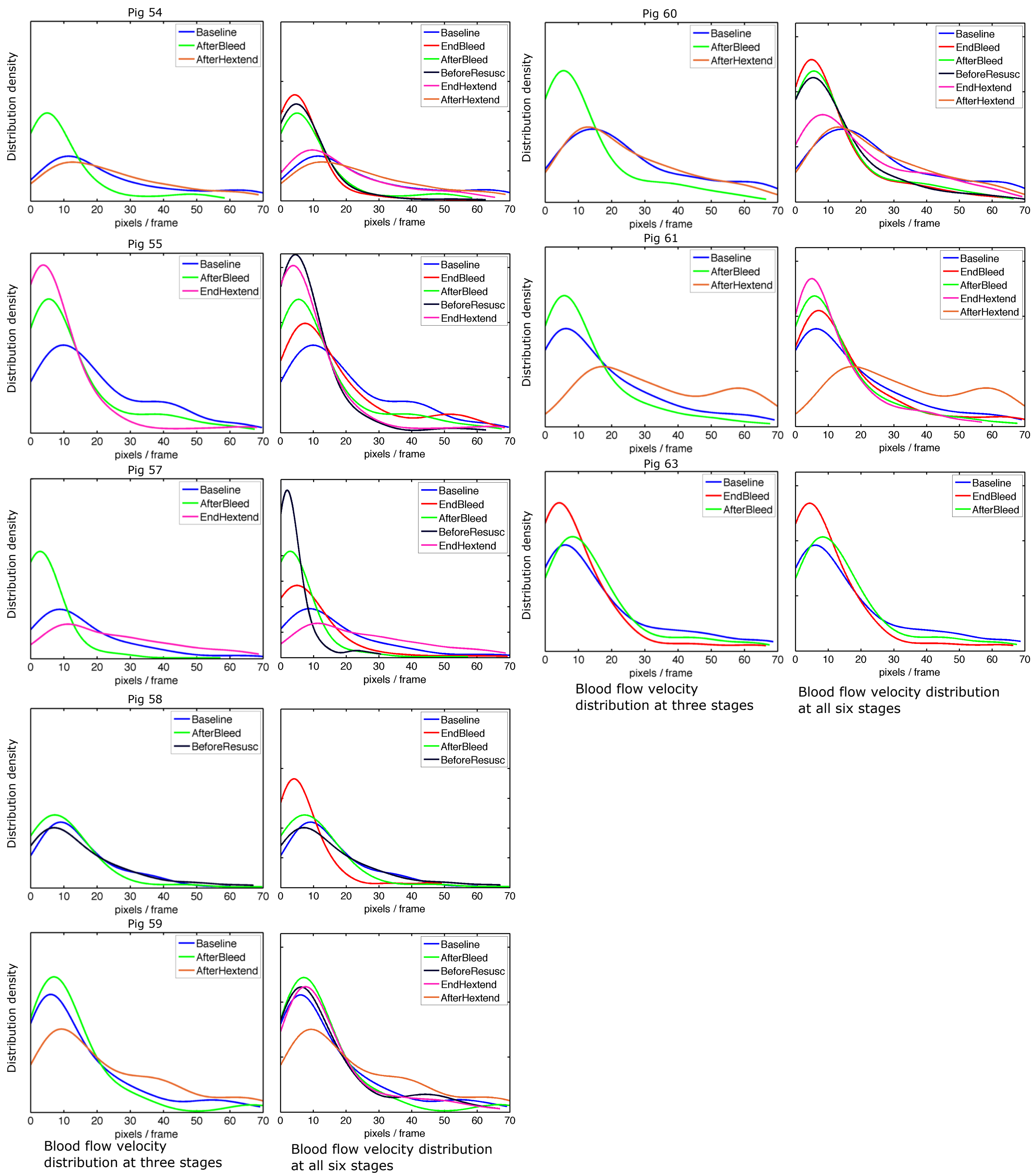

Figure 2: The estimated blood flow velocity distributions for pigs at different stages of the experiment (continued).