

### 3.7 Preliminary study for a medical application

In the previous section we have reported the algorithm to register the sequences in an accurate and robust manner. Now, we take the registration process for granted and we will focus on the medical application. The aim of achieving an actual medical use, although heart in mind during the research, has always been difficult to put into practice because our site is not inside a hospital. Also, since in our site we do not have direct clinical background from an ophthalmologist, we are unable to provide a direct clinical validation of our results.

This section is a preliminary study about the possible contribution of several image processing algorithms for the purpose of comparing a sequence of registered images. We explain the purpose motivating the registration process, and also the handicaps we met to make the sequences usable.

In the next section, we apply these proposes for the real medical application finally used at a colleague site; luckily, the collaboration with another group from Galicia provided us with the medical background we were aiming, together with a sense of the final interest for the clinical practice.

Clinitians are interested in large sequences of *SLO* images because the flow of contrast through the vessel tree reveals disfunctions, for instance:

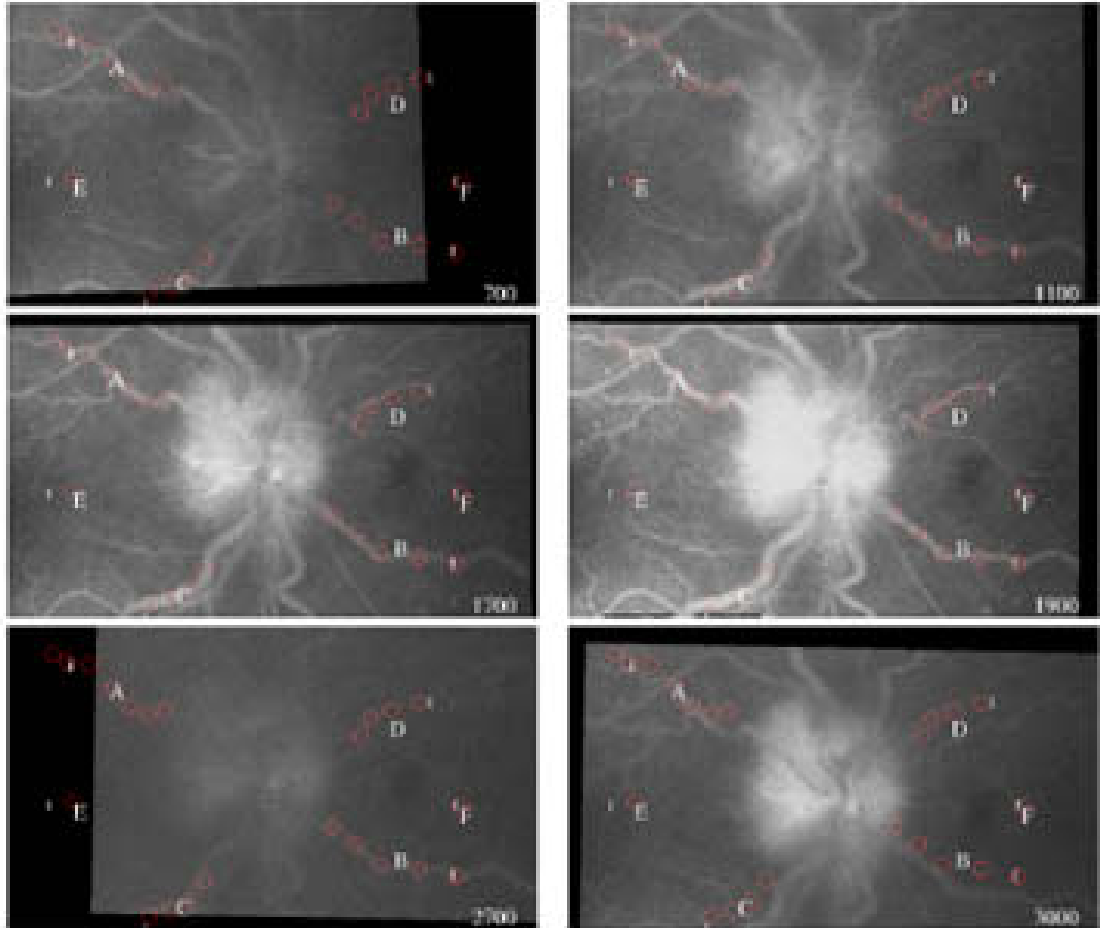
- leakage of blood outside the vessels, which eventually occludes the surrounding light receptors.
- blockage of blood at a knot in the vessel, which obstructs the normal circulation and may leave regions without proper irrigation.

An angiographic sequence reveals to the eyes of the expert many patterns which lead to a diagnosis. A normal sequence consists on the following phases (– for void, C for contrasted):

Phase	Arteries	Veins	Comment
1	–	–	the whole image has very low contrast
2	C	–	contrast starts to flow in
3	C	C	contrast has saturated the image
4	–	C	contrast stops to flow in, but still flows out
5	–	–	back to low contrast state

These phases can be seen with the help of the so-called saturation graphs. Saturation graphs depict the gray level of the *SLO* image at points selected by the clinician. The graph will show a different pattern according to the speed the blood flows through. Therefore, comparing the relative speed at different points, the clinician detects regions or vessels where the flow is too slow or too fast.

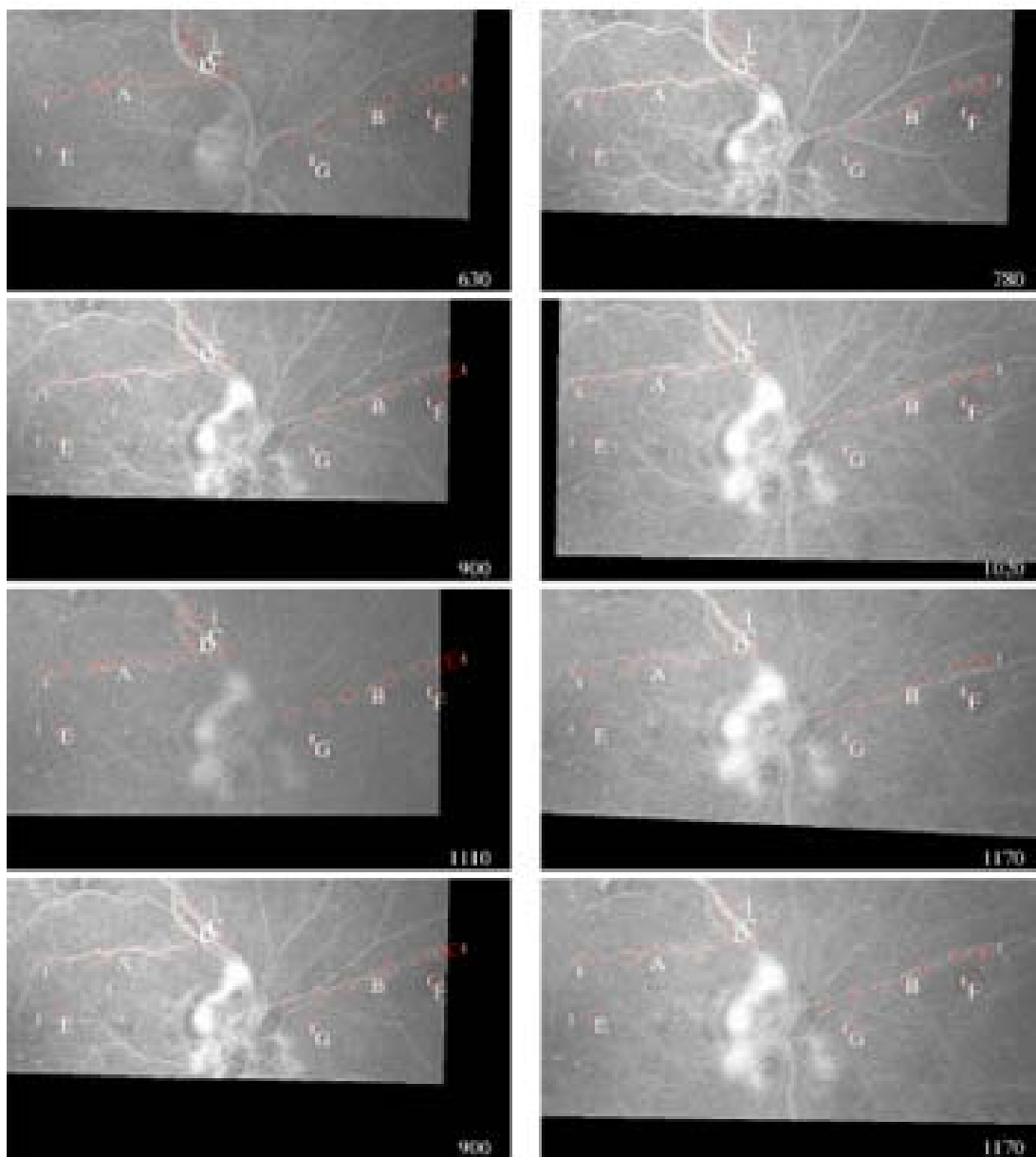
We have followed the steps in a fashion similar to a clinical protocol, and explored several issues relevant to the image processing part. Firstly, we have selected



**Figure 3.24:** Points from serie A where we computed the dilution graphs.

a set points of interest, most belonging to the vessel tree and some belonging to the background. Figures 3.24 and 3.25 illustrate the problems that show up:

- some points fall out of the image for a number of frames.
- some points seem to be missregistered for a number of frames, thus depicting background values.
- the algorithm must also consider frames not properly registered and identified as such.
- the raw value of a single pixel is very sensitive to the noise of the image, as we demonstrated in previous sections.



**Figure 3.25:** Points from serie B where we computed the dilution graphs. Note the variance of their position at each frame, despite their being registered. First 3 rows have been registered with the global setting, while last row local setting have been used.

The first item to examine was the problem of the noise in the images. See in figure 3.26 that the grey level is very unstable, making any interpretation very difficult.<sup>1</sup> Since this type curve was the first we obtained, we were disappointed and though it was caused by misregistrations. Then we realized that the noise of the image has to be taken into account, as a measure based on single pixel is very sensitive to it.

We have tried several operators with the aim of making the curve more stable:

- A maximum of a local neighbourhood.
- Convolution of the original image with a Gaussian kernel.
- Median or mean along 10 consecutive frames.

Figure 3.26 shows graphs for sequences A and B build with the gaussian and the median operators described above. We do not show the maximum (did not improve results), nor the mean (very similar to the median).

In previous section we showed that local registration improves the global accuracy, but since the improvement was difficult to quantify we left the final assessment up to the medical application which would use it. The saturation graph is a good chance for this purpose; we have computed them for a global and a local method. In figure 3.27 we give results for two points, extrapolable to the full set. The comparison of the two profiles, global and local, is clear even after the smoothing with a gaussian: the local method gives a profile similar in shape to the other but much more stable.

That proves that the local method has interesting properties which make a real effect on the final results. Other approaches to smooth the signal are also possible. They do not work with the intensities values in the images but with the profile treated as a signal. We have evaluated the Bezier curves approximating the  $n$  sampled points, as implemented in the *gnuplot* package. However, this approach could lead to false diagnosis as new values were introduced in the graphic, so we decided to employ the median operator. The graphics in the rest of the section employ this configuration.

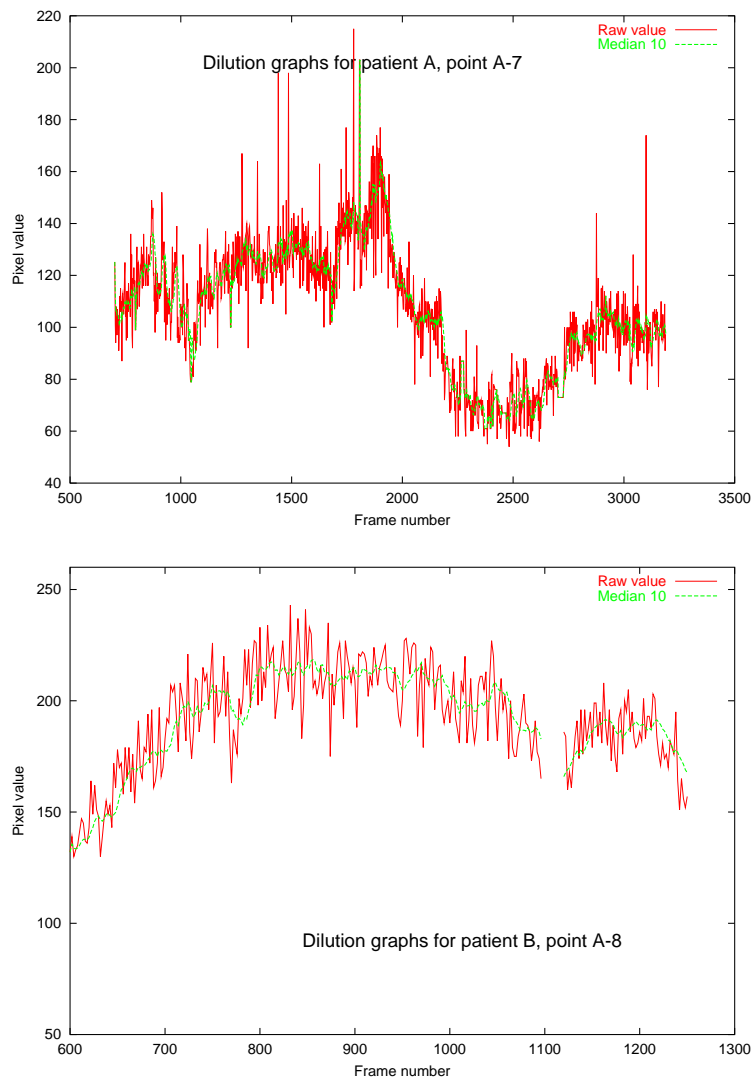
Finally we present the saturation graphs for all the sets of points defined in previous figures. We have selected points along the vessels, and also some belonging to the background for comparison.

We have not made any attempt in this section to interpret exhaustively the saturation figures, but still it is interesting to note some properties in figures 3.28 and 3.29:

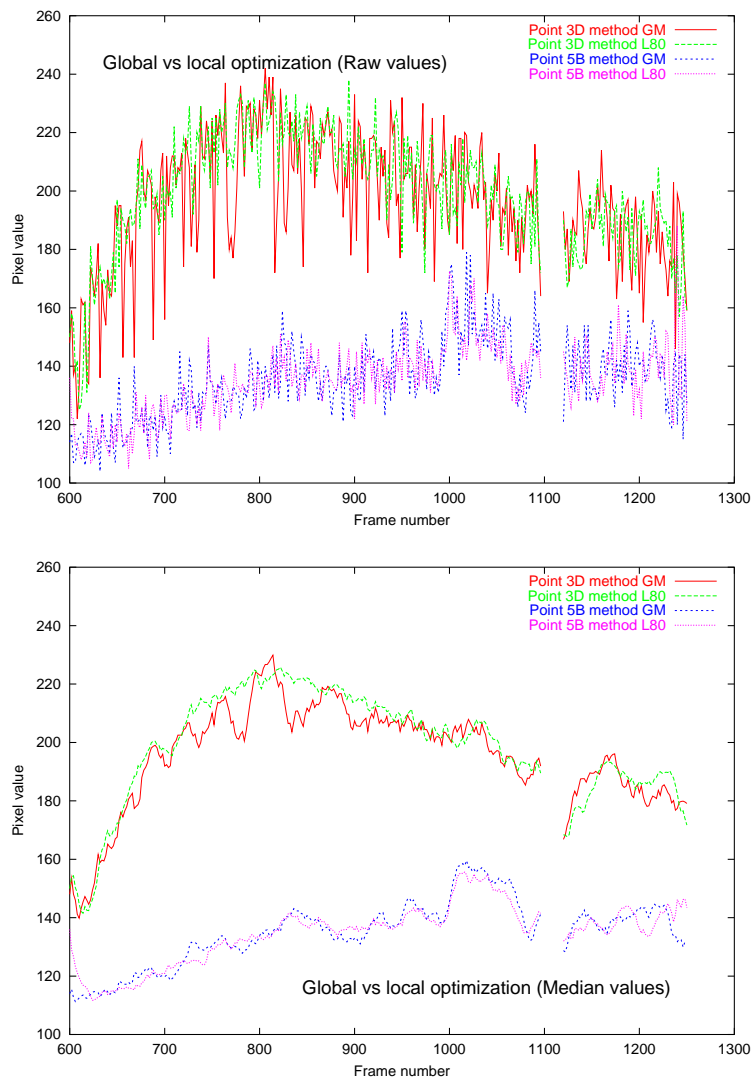
- graphs belonging to points from the same vessel generally do not overlap, but the gap in between is not constant.
- graphs of excentric points have lower value than their concentric counterparts.
- points from arteries fill well before points in veins.

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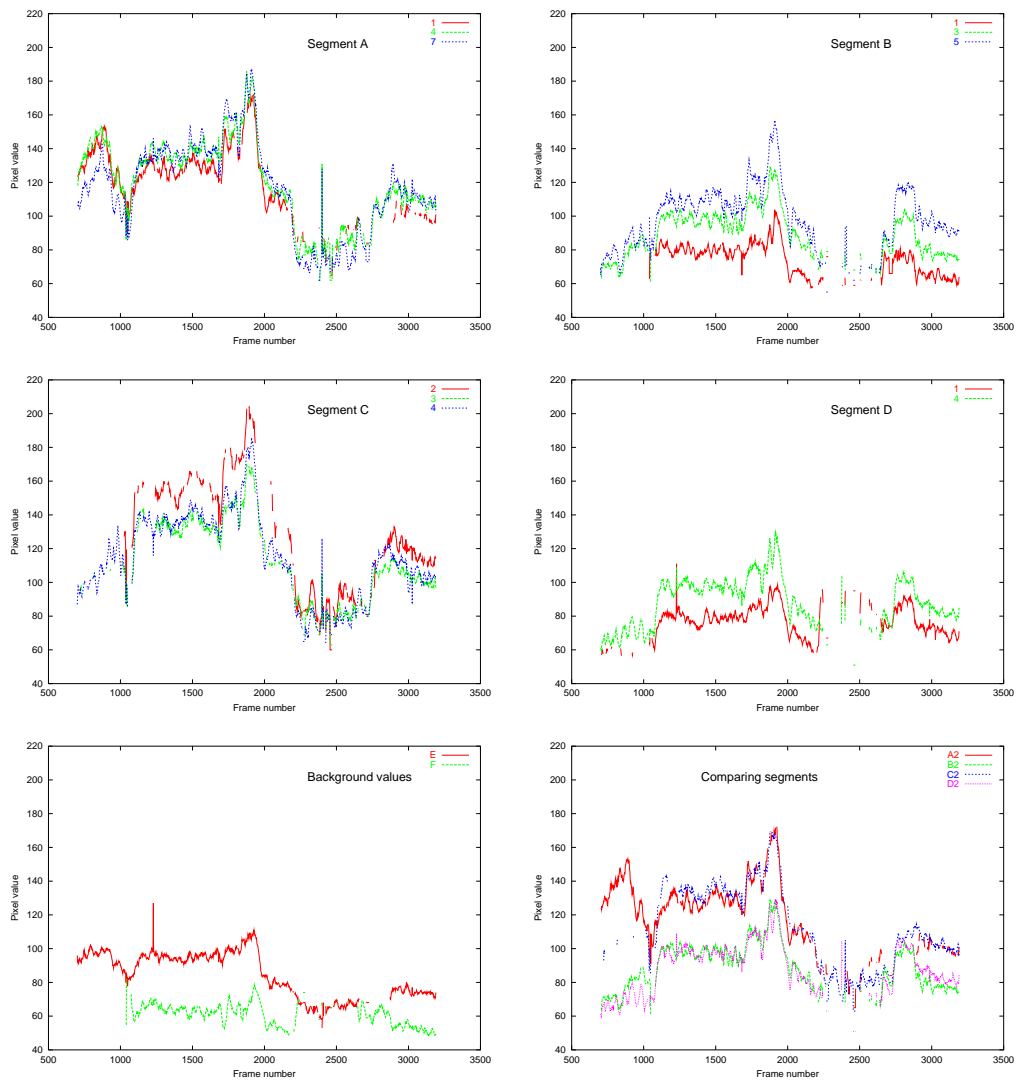
<sup>1</sup>All figures in this section have been drawn with the *gnuplot* package



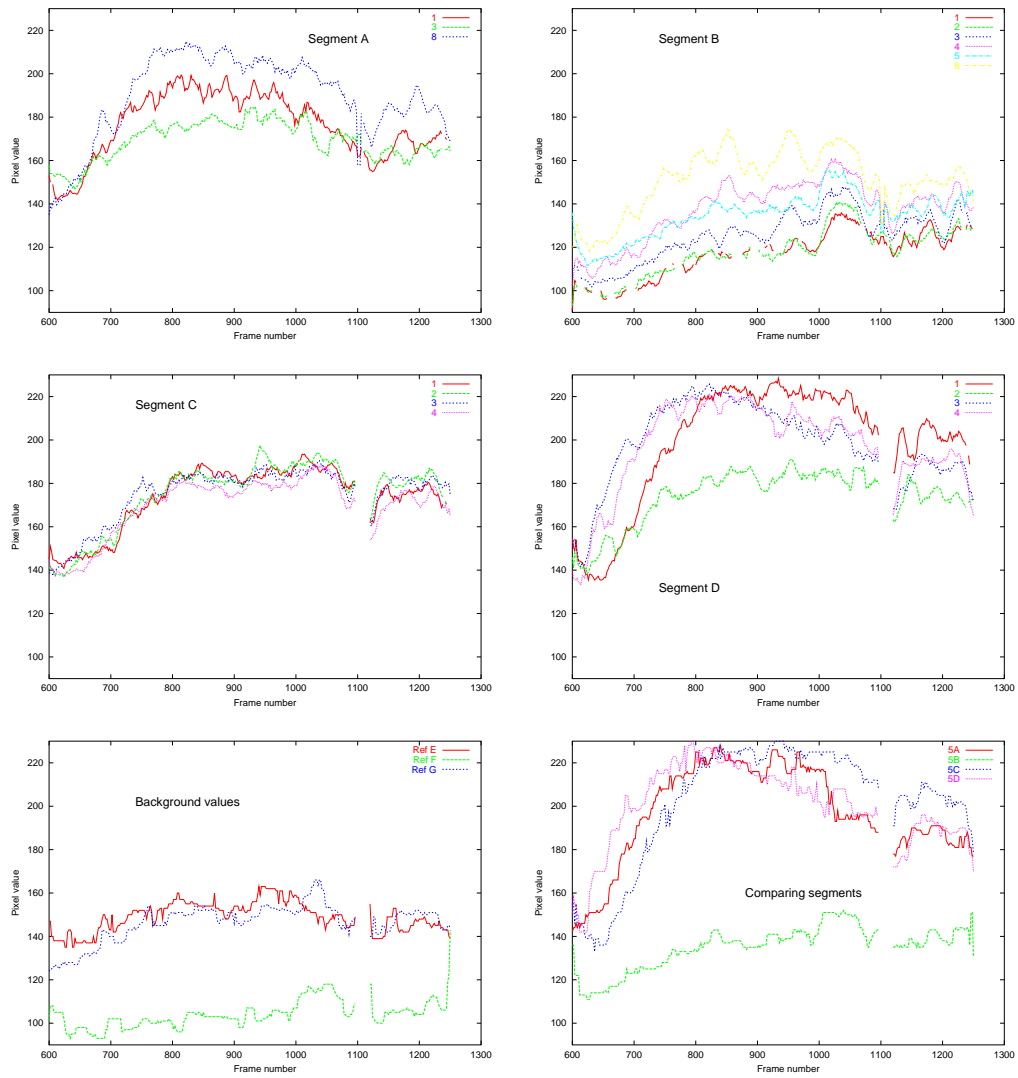
**Figure 3.26:** The intensity value must be normalized, otherwise raw values in *SLO* image are too noisy. The median value along 10 consecutive frames achieves this purpose.



**Figure 3.27:** This graphic illustrates the effect of the local registration *L80* vs. *GM* on the raw intensity values for patient B: on the top, the oscillations seen for the global method in the point 3D have been almost suppressed with the local method *L80*. At other points (Top, 5B) the local misregistrations were not severe, and the local method processes little improvement. For the same points, however, the median value along 10 consecutive frames achieves a smoothing effect similar to that of the local method, being faster and more simple to compute. The curves are labeled according to the number in figure 3.25.



**Figure 3.28:** Dilution curves for segments A, B, C and D for Patient A and method *L80*. Bottom row, left: background values. Right: comparing different segments.



**Figure 3.29:** Dilution curves for segments A, B, C and D for Patient B and method *L80*. Bottom row, left: background values. Right: comparing different segments.