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Study on basis function methods reliance on θ_3 parameter limits – study with simulated [^{11}C]raclopride images

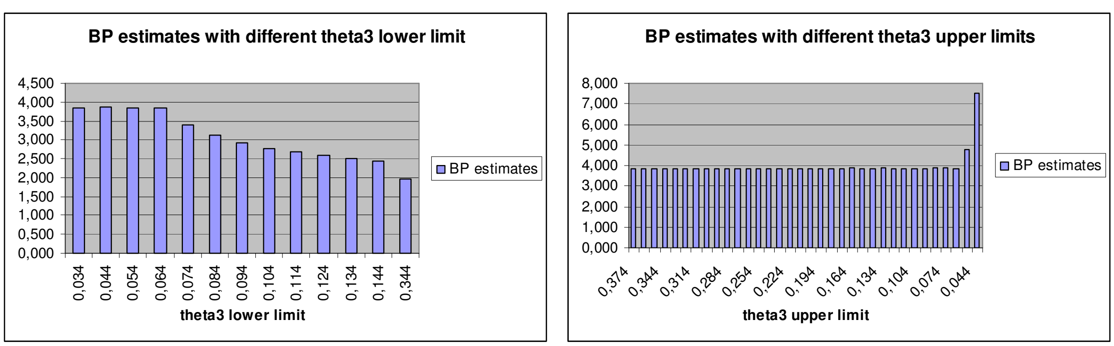
A simulated dynamic image was used to test the effect of θ_3 limits in practice. The dynamic image was simulated based on rate constants taken from a [^{11}C]raclopride study. After that different amounts of Gaussian noise were included in the image (noise level=10, 200, 400, 600). Simulations are described in detail in appendix A of tpcmod0027.

Materials and Methods

Estimations for the image with no noise were done with a high range of different limits. Either the lower or the upper limit was fixed and the other limit value was altered. When upper limit was fixed to 0.374 the lower limit values ranged from 0.034 to 0.344 and when lower limit was fixed to value 0.034, the upper limit values ranged from 0.044 to 0.374. Based on these results we chose the θ_3 upper and lower limit ranges for modeling noisy images. Lower limit values 0.06, 0.05, 0.04, 0.03 were tried with the upper limit fixed to 0.6 and when lower limit was fixed to 0.06 then upper limit was ranged from 0.6 to 0.3.
The formulas for calculating the true binding potential value (3.43) for basal ganglia of the simulated image are described in [1].

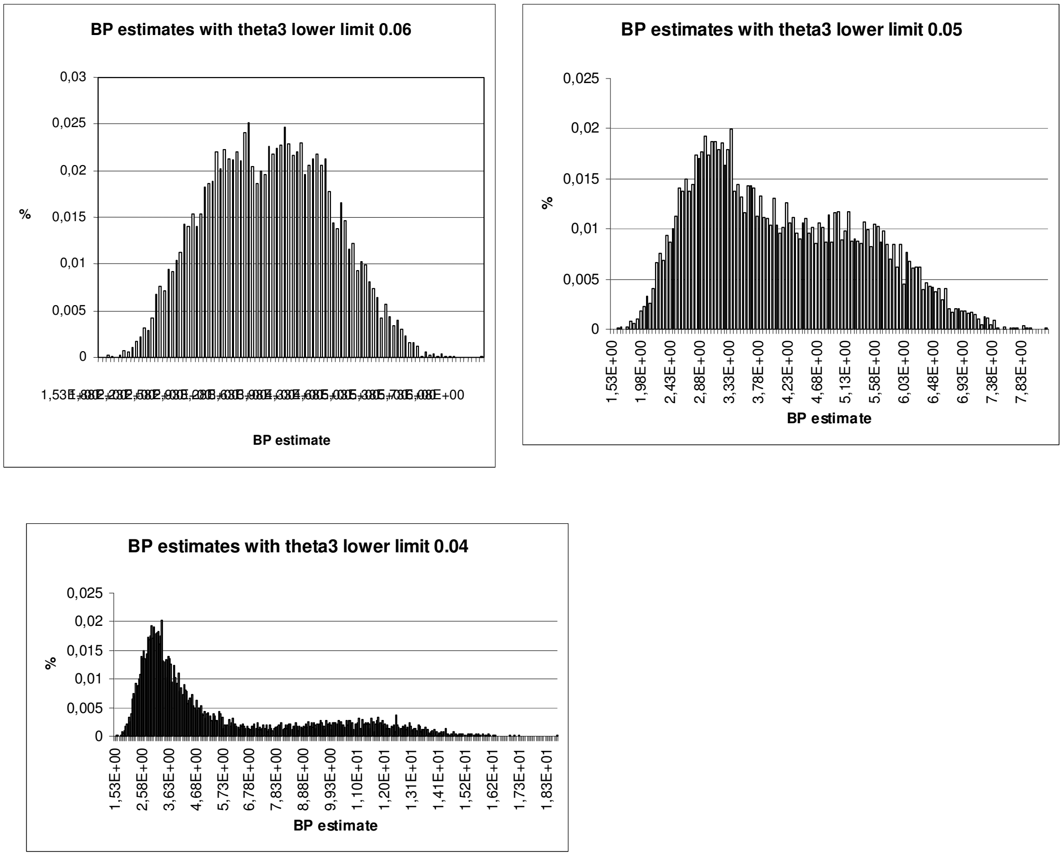
Results

Different θ_3 limits for modeling of image with no noise are described above. The resulting estimates are shown in picture 1 - it is clear that altering of the lower limit has more radical effects on the results than altering of the upper limit. The right picture shows upper limit changes and clearly the upper limit value has effect on the BP estimates only when it starts to reach lower limit, which was fixed to 0.034. On the left picture we can notice a clear trend: the higher the lower limit for θ_3 is, the smaller estimate we get for BP. Value 0.74 as the lower limit results to best estimate (upper limit was fixed to value 0.374).



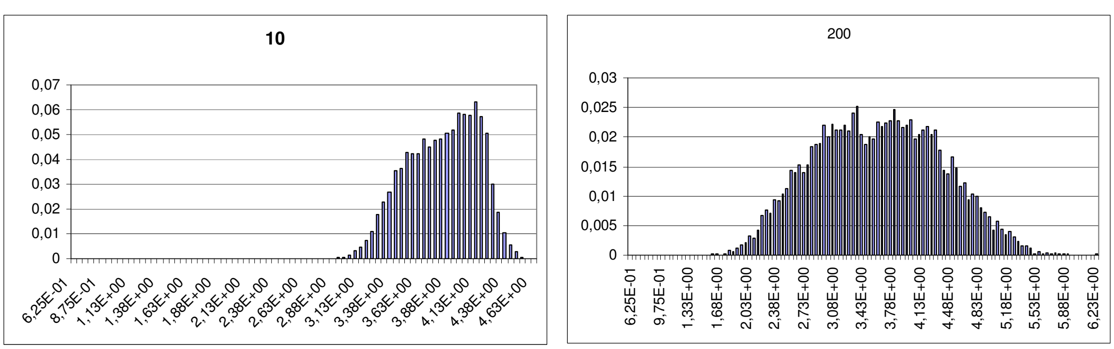
Picture 1. Effect of θ_3 limits on BP estimate (no noise was present).

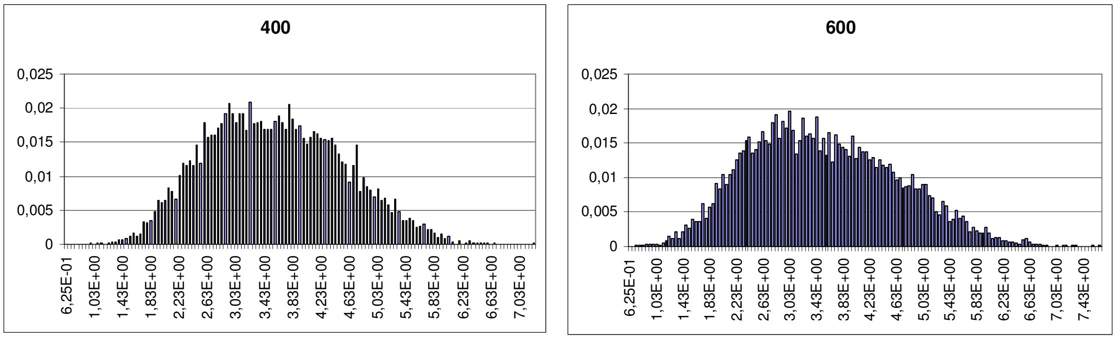
Naturally the smaller the lower limit of θ_3 was, the less θ_3 estimate ran into that limit in all the estimations. But from picture 2. we can also see that small lower limit caused long tail to the right end of the BP distribution when modeling noisy images. This long tail corrupted the BP estimate to be larger than it should. Lower θ_3 limit value 0.03 already caused such spread distribution that Excel bar chart couldn't handle the data.



Picture 2. BP values from basal ganglia areas of parametric images generated from dynamic image with noise level 200 using different lower limits for θ_3 parameter.

We compared also distributions of BP estimates when good θ_3 limits were used in implementing parametric images from dynamic images corrupted with different amounts of Gaussian noise (picture 3). The obvious effect of spreading of the distribution was seen when more noise was added to the dynamic image. But also the peak of the distribution seemed to move little bit to the left and closer to the real value of BP when more noise was introduced.





Picture 3. BP values from basal ganglia areas of parametric images generated from dynamic image with different noise levels (θ_3 limits =0.06-0.6).

Discussion

The "invisibility" of θ_3 running into its limits can be seen problematic. With invisibility I mean that BP distribution looks fine although maybe in half of the pixels θ_3-estimate has reached either the lower or the upper limit. Anyhow it seems that the fact that θ_3 is reaching its limits often is not proportional to getting bad estimates of BP, on the contrary the relationship seems to be almost opposite.

Thus the main aim in choosing θ_3 parameter limits should not be to get low "running into limits -rate" but to keep the BP distribution from getting a long tail.

Still remaining problem is that badness of data won't necessarily show in BP results. This would require introduction of some kind of mechanism that would warn user of basis function method about bad data.

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References

1. Turku PET Centre Modelling report TPCMOD0027 Appendix A