Comparison of low-distortion methods for calculating diffusion-related metrics in metastatic brain tumors and structures

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Introduction

Diffusion-weighted imaging (DWI) in MRI is a promising method for adaptative radiotherapy. The aim of this study is to compare several diffusion-related metrics derived from DWI in different brain structures and metastasis.

Materials and Methods

Each patient undergone a DWI turbo-spin echo sequence (DWI-TSE) with b = 0, 1000 s/mm^2, a DWI echo-planar imaging sequence (DWI-EPI) with b = 0, 50, 100, 200, 500, 1000 s/mm^2 (distortion corrected) and dynamic studies (Ktrans) (Fig. 1)

Diffusion-related parameters of five brain structures (brainstem, ventricles, vitreous humor, grey and white matter) and eight brain metastatic tumours from five patients were calculated using four models [1] :

- Monoexponential: for TSE and EPI series (ADC-TSE and ADC-EPI, b = 0, 1000 s/mm2)
- Double-monoexponential: for EPI to return ADC_{fast} (b = 0, 200 s/mm^2) and ADC_{slow} (b = 500, 1000 s/mm^2) (only ADC_{slow} is diffusion-related)
- IVIM: fitting all b-values with the bi-exponential model implemented in two ways: with all the parameters free (D_{free}) and in two steps (D_{2st}), first adjusting D for b>200 s/mm^2

Results

ADC-TSE and ADC-EPI show significant similar results for all the structures (Table 1). There are no significant differences between ADC-EPI$_{slow}$ and D_{2st}, while D_{free} present lower values. Poorly vascularized areas from heterogeneously vascularized tumours show lower ADC and D values than well vascularized (Fig. 2).

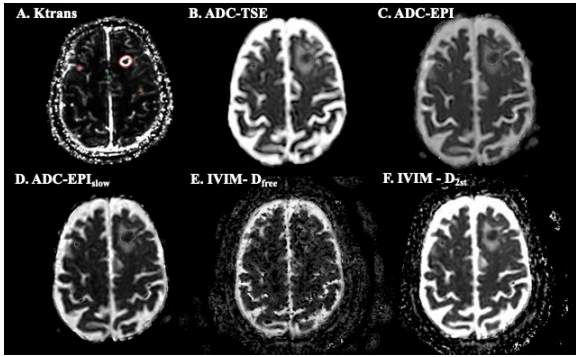

Figure 1. Diffusion-related maps from a patient with 3 metastases of NSCLC

Table 1. Values of Ktrans, ADC (TSE, EPI and EPIslow) and D (free and in two steps) for five structures and eight CTVs of 5 patients. Tumours are divided into heterogeneously and homogeneously vascularized, delineated on Ktrans maps.

Structures (n = 5)	Volume	ADC-TSE	ADC-EPI	ADC-EPI $_{slow}$	D_{free} - IVIM	D_{2st} - IVIM	Ktrans
Brainstem	29.06 ± 2.15	1.05 ± 0.11	1.21 ± 0.22	0.73 ± 0.06	0.78 ± 0.05	0.74 ± 0.03	- -
Grey matter	472.3 ± 75.35	1.53 ± 0.22	0.153 ± 0.25	1.18 ± 0.21	1.08 ± 0.19	1.25 ± 0.18	- -
Ventricles	23.74 ± 6.25	2.55 ± 0.25	2.44 ± 0.31	1.97 ± 0.32	1.84 ± 0.25	2.08 ± 0.24	- -
Vitreous humor	3.75 ± 0.27	3.19 ± 0.21	3.45 ± 0.26	3.18 ± 0.45	2.41 ± 0.26	2.86 ± 0.06	- -
White matter	791.3 ± 77.05	0.94 ± 0.09	0.92 ± 0.11	0.79 ± 0.08	0.64 ± 0.04	0.79 ± 0.05	- -
Heterogeneous (n = 3)							
Whole CTV	5.17 ± 3.12	1.13 ± 0.18	1.09 ± 0.13	0.94 ± 0.08	0.79 ± 0.16	0.95 ± 0.12	0.11 ± 0.04
well vascularized CTV	1.81 ± 1.68	1.13 ± 0.17	1.10 ± 0.15	0.94 ± 0.08	0.85 ± 0.15	0.94 ± 0.15	0.16 ± 0.05
poorly vascularized CTV	1.09 ± 0.89	0.93 ± 0.21	0.92 ± 0.24	0.77 ± 0.11	0.63 ± 0.24	0.79 ± 0.16	0.04 ± 0.03
Homogeneous (n = 5)							
Whole CTV	0.14 ± 0.08	1.20 ± 0.35	1.29 ± 0.27	1.11 ± 0.26	0.93 ± 0.05	1.11 ± 0.23	0.04 ± 0.03

Values are shown as mean ± standard deviation

Units: Volume (cm^3); Ktrans (min^{-1}); ADC (10^{-3}mm^2/s); D (10^{-3}mm^2/s)

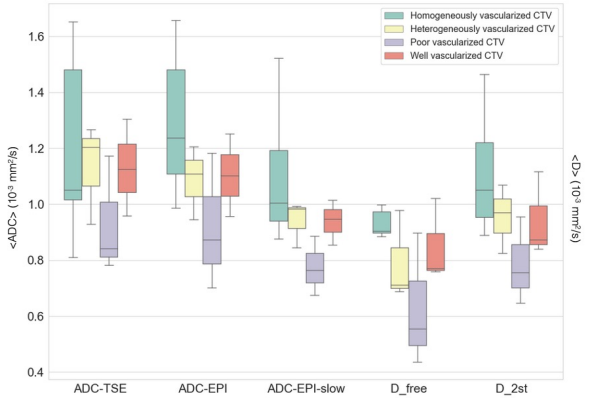

Figure 2. Boxplot of mean ADC and D values calculated with different models and for different metastatic structures

Conclusions

- ADC from TSE and EPI show similar values, but due to acquisition time, EPI is more suitable for IVIM studies since multiple b-values are needed.
- Implement IVIM model in 2 steps may be more accurate than with all the parameters free, and equivalent to ADC_{slow} values.
- Lower ADC and D values in heterogeneous tumours may represent poor vascularized areas.

Acknowledgments

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References

[1] Klaassen, R. et al. *International Journal of Radiation Oncology, Biology, Physics* (2018)