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ORIGINAL ARTICLE/ARTICLE ORIGINAL

Stereo-electroencephalography (SEEG) in children surgically cured of their epilepsy

La stéréoélectroencéphalographie (SEEG) chez les enfants guéris par la chirurgie de leur épilepsie

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Summary
Purpose. — SEEG in children has a low morbidity and leads to a good surgical outcome, in particular in younger patients. We analysed, in detail, the SEEG data of patients that were subsequently cured by surgery.
Methods. — We selected the 48 children explored between 2009 and 2013 in our centre and surgically cured after SEEG-based resections with at least one-year follow-up. We retrospectively studied demographic and surgical data and paid particular attention to the data acquired during the invasive recording. Moreover, we compared the children younger than 5 years of age (group 1: 17 children) to those older than 5 years of age at the time of exploration (group 2: 31 patients).
Results. — SEEG was well tolerated. Only one patient had slight intracerebral bleeding seen on the post-operative CT-scan without any clinical consequence and which did not prevent the

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recording. SEEG explored at least four lobes in 59% of patients, either because of a suspected very widespread epileptogenic zone or because of the lack of a precise hypothesis. Auras were recorded only in group 2 (32% of patients, $P = 0.0009$). Despite these difficulties, SEEG led to tailored resections including multilobar resections in 14% and infralobar resections in 69% of patients. The electrical pattern of seizures had no particularities as compared with adults. Interictal spikes and slow waves outside the resection zone were significantly less frequent in group 1 ($P = 0.02$). In symptomatic epilepsies, the lesion matched the irritative zone in only 11% of patients and the ictal onset zone in 32% respectively.
Conclusion. — Our study confirms the low morbidity of SEEG in children. SEEG can disclose a limited epileptogenic zone. Our data suggest that the epileptic network is less complex in younger patients, which has to be confirmed by a quantitative analysis of SEEG signals.

MOTS CLÉS
Chirurgie de l'épilepsie ;
Explorations invasives ;
Stéréoélectroencéphalographie ;
Stimulations électriques ;
Enfants ;
Résections corticales focales

Résumé
Introduction. — La SEEG chez les enfants a une morbidité basse et conduit à de bons résultats chirurgicaux, en particulier chez les plus jeunes. Nous avons analysé en détail les données des patients guéris par la chirurgie.
Méthodes. — Nous avons sélectionné les 48 enfants explorés entre 2009 et 2013 dans notre centre et guéris par une résection corticale fondée sur la SEEG avec au moins un an de suivi. Nous avons étudié rétrospectivement non seulement les paramètres démographiques, mais surtout les données invasives. De plus, nous avons comparé les enfants de moins de 5 ans (groupe 1 : 17 patients) à ceux âgés de plus de 5 ans lors de la chirurgie (groupe 2 : 31 patients).
Résultats. — La SEEG fut bien tolérée. Un seul patient eut une petite hémorragie parenchymateuse vue sur le scanner post-opératoire, qui n'empêcha pas l'enregistrement. La SEEG explora au moins 4 lobes chez 59 % des patients, parce que la zone épileptogène suspectée était étendue, ou bien en l'absence d'hypothèse précise. Seuls les patients du groupe 2 rapportèrent une aura (32 % des patients, $p = 0{,}0009$). Malgré ces inconvénients, la SEEG conduisit à une résection à façon, multilobaire chez 14 % et infralobaire chez 69 %. La décharge critique n'avait pas de particularités par rapport à l'adulte. Les pointes-ondes intercritiques en dehors de la zone de résection étaient significativement moins fréquentes dans le groupe 1 ($p = 0{,}02$). Dans les épilepsies symptomatiques, la lésion s'est avérée coïncider avec la zone irritative chez seulement 11 % des patients, et avec la zone de départ des crises seulement chez 32 %.
Conclusion. — Notre étude confirme la faible morbidité de la SEEG chez les enfants. La SEEG peut mettre en évidence une zone épileptogène limitée. Nos données suggèrent que le réseau épileptique est moins complexe chez les patients jeunes, ce qui devrait être confirmé par une analyse quantitative des signaux SEEG.

Despite advances in imaging, invasive explorations are still required in some children with drug-resistant focal epilepsy in order to delineate the epileptogenic region and/or to determine its relationship with functional cortex [5,15,14].

Stereo-electroencephalography (SEEG) is one of the available invasive methods. Since the princeps description by Talairach et al. in adults [18], Kahane and Francione [16] have formalised the methodology taking into account the development of modern imaging. SEEG is well adapted for children. A minimum bone thickness is required in order to anchor the hollow pegs for the electrode insertion and attachment; this aspect of anatomical development is complete by two years of age and must be confirmed by a CT-scan performed before the invasive exploration. Therefore, many teams working with SEEG deal with children [19,17,11], but few papers are dedicated to SEEG in children [2,20,12]. Cossu et al. specifically addressed SEEG in children younger than 45 months [4]. Morbidity is low, ranging from 0 to 3% [2,20,12]. We described the largest SEEG series and took a particular group of children younger than 5 years into consideration, showing that the morbidity is as low as in older patients and the surgical outcome much better with 79% of children younger than 5 years in Engel class 1A [20]. In this previous paper, we did not find any clear-cut explanation for this good outcome. One hypothesis could be differences in electroclinical patterns. Our population was too heterogeneous to enable us to verify this hypothesis properly. Subsequently, we performed a descriptive analysis of a population of children cured by surgery and analysed the data globally and according to age. Our aim was to identify trends that could help our management in the future.

Patients and methods

We retrospectively studied all of the 116 children having undergone SEEG exploration between January 2009 and April 2013 in our department. Among them, we selected the 48 children for whom the SEEG led to a successful