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Treatment of pediatric hydrocephalus by neuroendoscopic choroid plexus coagulation

Tratamento da hidrocefalia pediátrica pela coagulação neuroendoscopica do plexo coróide

Roberto Alexandre Dezena

Abstract: This study aims to review historical aspects and the rebirth of the neuroendoscopic choroid plexus coagulation (NCPC) as treatment of pediatric hydrocephalus. The literatures covering this topic were reviewed through PubMed. The first NCPC procedure goes back to the early 1930s. After the development of other treatment methods and the understanding of cerebrospinal fluid (CSF) dynamics, the application of NCPC dramatically decreased by 1970s. In 2000s, there was a rebirth of NCPC in combination with endoscopic third ventriculostomy (ETV). NCPC remains one of the treatment options of pediatric hydrocephalus in selected cases. NCPC might provide a temporary reduction in CSF production to allow the further development of CSF absorption in infants. Adding NCPC to ETV for infants with communicating hydrocephalus may increase the shunt independent rate thus avoiding the consequence of late complication related to the shunt device. This is important for patients who are difficult to be followed up, due to geographical and/or socioeconomic difficulties. And also adding NCPC to ETV for obstructive hydrocephalus in infants may also increase the success rate. Furthermore, NCPC may be an option for cases with high chance of shunt complication such as multiloculated hydrocephalus, extreme hydrocephalus and hydranencephaly. In comparison with the traditional treatment of CSF shunting, the role of NCPC needs to be further evaluated particularly in concern to the neurocognitive development.

Keywords: pediatric hydrocephalus, neuroendoscopic choroid plexus coagulation, endoscopic third ventriculostomy.

Resumo: O presente estudo tem como objetivo revisar os aspectos históricos e do renascimento da técnica de coagulação neuroendoscópica do plexo coróide (NCPC) para tratamento da hidrocefalia pediátrica. Foi realizada uma revisão bibliográfica utilizando-se o PubMed. O primeiro procedimento NCPC remonta a década de 1930. Após o desenvolvimento de outros métodos de tratamento e a compreensão da dinâmica do líquido cefalorraquidiano (LCR), a aplicação da NCPC reduziu drasticamente na década de 1970. Na década de 2000, ressurgiu a NCPC, em combinação com a terceiro ventriculostomia endoscópica (ETV). A NCPC continua sendo uma das opções para o tratamento da hidrocefalia pediátrica em casos selecionados. A NCPC proporciona a redução temporária da produção de LCR para permitir o desenvolvimento da absorção do LCR na criança. Adicionando NCPC na ETV para crianças com hidrocefalia comunicante pode-se aumentar a taxa independente do *shunt*, evitando assim, consequentes complicações tardias relacionadas ao aparelho. Este *shunt* é importante para os pacientes com difícil seguimento, devido às dificuldades geográficas e/ou sócio-econômicas. Além disso, quando adicionado A NCPC somada à ETV para a hidrocefalia obstrutiva no lactente, pode aumentar a taxa de sucesso. A NCPC pode ser uma opção para os casos com grande chance de complicação do *shunt*, como hidrocefalia multiloculada, extrema hidrocefalia e hidroanencefalia. Em comparação com o tratamento tradicional, o papel do NCPC precisa ser bem avaliada, em particular no que respeita ao desenvolvimento neurocognitivo.

Palavras-chave: hidrocefalia pediátrica, coagulação neuroendoscópica do plexo coróide, terceiro ventriculostomia endoscópica.

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Introduction

Pediatric hydrocephalus is one of the most frequently diagnosed diseases in pediatric neurosurgical practice. Approximately 60% of the total cases of hydrocephalus in children are congenital or acquired in childhood. It's a typical surgical disease, and if left untreated it is lethal in most cases. Traditionally, shunts are the main treatment since 1940s. However, sometimes shunt dependency in children with hydrocephalus is a terrible problem, and it is more dangerous in emerging countries because of the difficulties to access prompt neurosurgical intervention, in cases of infection or shunt malfunction.[8,22,23]

In this scenario, mainly in obstructive hydrocephalus, neuroendoscopic techniques such as endoscopic third ventriculostomy (ETV) become vitally important in the management of these patients. ETV is successful in about 80% of children older than 1 year of age, regardless of the cause of obstructive hydrocephalus. For infants younger than 1 year of age, isolated ETV remains controversial, probably because of the deficiency in cerebrospinal fluid (CSF) absorption. Benjamin C. Warf, at CURE Children´s Hospital of Uganda, hypothesized that the addition of neuroendoscopic choroid plexus coagulation (NCPC) at the time of the ETV, to simultaneously reduce the rate of CSF production, might improve the outcome.[22]

This old neuroendoscopic procedure of the early 20th century, abandoned due to limited technology and frequent complications, has been reinvented and adapted to current neurosurgery.

Historical aspects

Faivre, in 1854 and Luschka, in 1855 were the first researchers to suggest that the choroid plexus is the source of CSF.[3,29] Cushing supported this hypothesis

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through intraoperative observations.[4] Extrachoroidal fluid production was suggested by Weed in 1914, by animal studies.[29]

Dandy, in 1918, demonstrated in an animal study that unilateral hydrocephalus was produced when the 4th ventricle was blocked together with the access through the foramen of Monro to the contralateral plexectomized lateral ventricle.[5,30]

Furthermore, in the same year, in another animal study he also demonstrated that the choroid plexus produces CSF. Based on this result, he performed choroid plexus extirpation in four infants with communicating hydrocephalus by open surgery. In this series, one infant with moderate hydrocephalus and myelomenigocele was well on 10 months follow-up, and the other three infants with severe hydrocephalus died within 4 weeks after the operation.[5,30]

After, in 1932, Dandy also used a rigid Kelly cystoscope to inspect the lateral ventricles in two hydrocephalic children.[6] Cauterization of the choroid plexus was attempted in one case. He further detailed the technique of endoscopic coagulation of the choroid plexus in 1938.[7,30]

Isolated NCPC was first described by Putnam, in 1934[30].In the subsequent years, besidesNCPC, other surgical treatments of hydrocephalus were introduced including ETV and extrathecal CSF shunts. In a review, from 1934 to 1957, there were 95 cases of NCPC. The mean mortality rate was 15 %, while the mean success rate was 60% with an average follow-up period of 8 years.

On the other hand, there were 1087 cases of various kinds of CSF shunt, including 230 ventriculo peritoneal shunts (VPS). The mean mortality rate was 10%, and the mean initial success rate was 60% with an average follow-up time of 2 years. The result of the reviews showed a shift from NCPC to shunts,

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perhaps due to limited technology. On the other hand, the late complication rate for shunt was 57%.[17,30]

Scarff, in 1970, published the first large series of NCPC cases, his own series of 39 children treated during 23-year period, with 67% of success[18]. Milhorat, in 1974[13], reported his series of 12 cases underwent choroid plexectomy. Among 11 survivors, 8 (72%) failed and required further shunt[13]. After this report, that NCPC in rhesus monkeys reduced CSF production by only 40%, it declined in favor of the shunts.[30] Neuroendoscopic literature from the 1980s to 2004, the success rate of NCPC was between 30 and 52%.[9,10,16] In small series, two out of three cases were successful.[1,14,30]

Griffith, in 1986, gave a detailed account of endoscopic intracranial neurosurgery, through a report of the results of 71 patients who received NCPC with or without shunt from 1972 to 1982[9]. The selection criteria were infants with hydrocephalus who had progressively enlarging head circumference with ventricles grossly dilated and absent superficial CSF space on CT scan. Behavioral changes were also considered. In his series, 30 % were not shunt dependent.

The success rate was 54, 58, and 22 % for myelomenigocele, communicating, and obstructive hydrocephalus groups, respectively. The same author, in 1990,[10] further reported the results of 32 childhood hydrocephalus cases treated by NCPC between 1985 and 1988 with CT scan examination. Eighteen cases were below the age of6 months. Patient selection was the same as in his previousreport. In addition, all cases showed marked ventricular dilatation on preoperative CT scan.

Different to his previousseries, he added postoperative perfusion of the ventricularsystem with artificial CSF to clear the postcoagulation blood and protein released to the CSF. The average follow-up time ranged from 1 to 4

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years. Fifty-two percent of the patients were shunt independent. Those that required shunting was all in an interval of ≤12 weeks, except one. Among the successful group, most of the patients showed a head circumference similar to the preoperative size.[30]

Pople and Ettles, in 1995[16], reviewed the results of NCPC in 116 children with hydrocephalus operated from 1973 to 1993.[15,16] The mean age was 2 years and the overall hydrocephalus control rate was 49.5%. Among communicating hydrocephalic children with slow to moderate rate of increase in head circumference, the long-term control rate was 64%. On the other hand, only 35% achieved long-term control without CSF shunts in patients presented with tense fontanels and rapidly progressed hydrocephalus. The authors suggested that the main indication for NCPC was mildly progressive communicating hydrocephalus in infants.

In these patients, it seemed that the balance between production and absorption of CSF could be restored by only a small reduction in outflow from the choroid plexus of the lateral ventricle. In contrast, NCPC was not recommended for rapidly progressive hydrocephalus with acutely raised intracranial pressure.[15,16,30] In fact, up until now, these first experiences were quite controversial, perhaps because of technological limitations.[8]

Rebirth

In the late 1990s to early 2000s, due to advancement in neurosurgical technology, the mortality rate in isolated NCPC has decreased, but the key issue for its decline in clinical practice is its efficacy[30]. At this time, Warf´s Uganda series, for the first time investigated the benefits of ETV associated to NCPC, again arousing interest in this technique. It was concluded that ETV/NCPC procedure is superior to ETV alone in infants younger than 1 year of age, particularly among those with non-post infectious hydrocephalus and

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myelomeningocele, but longer follow-up with neurocognitive assessment is necessary.[22]

Dr. Warf's published results of ETV/NCPC for children in Africa, and most of the subjects in the study were infants.[22] The long-term outcome and neurocognitive outcome were reported in 2008[24] and 2009[21] respectively. They highlighted that shunt dependency in children with hydrocephalus is more dangerous in developing countries than in developed countries due to the limits to access competent centers in the event of shunt malfunction or infection.[22] Between 2001 and 2004, ETVs were performed as the initial treatment in 550 patients presented with hydrocephalus. After evaluating the initial results, it was decided to perform bilateral lateral ventricle NCPC including the temporal horn using flexible endoscope from a single approach in addition to the ETV to assess the benefit.

Warf and Campbell, in 2008[24], reported the long-term result of ETV/NCPC for East African infants with hydrocephalus related to myelomeningocele. Among the 338 infants whose myelomeningocele was repaired prior to 6 months of age, 258 patients (66%) who had been followed up for >6 months required treatment for hydrocephalus. There were 93 cases (mean age, 3 months) who had completed ETV/NCPC with >1 month follow-up.

They have achieved a successful (shunt independent) rate of 76%. This successful rate was higher in ETV/NCPC cases than those by ETV alone for infant age 6 months or younger with hydrocephalus in association with myelomeningocele as reported in the literature.[11,20] Stillin 2009, Warf et al.[21]reported the neurocognitive outcome and ventricular volume in children with myelomeningocele treated for hydrocephalus in Uganda. The modified Bayley Scales of Infant Development (BSID-III) and the frontal/occipital horn ratio (FOR) were used to compare three groups of patients with myelomeningocele. For the modified BSID-III, there was no statistically significant difference

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between treatment groups of VPS and ETV/NCPC. For the ventricular size, the mean FOR was 0.7, 0.65 and 0.62 for the VPS, the ETV/NCPC and the not required treatment groups showed no statistically significant difference. The authors suggested that future work is needed to compare outcomes by using a larger control group of children treated primarily with VPS shunt placement. The same group has applied ETV/NCPC in encephalocele, with a successful rate of 85%[27], and in obstructive hydrocephalus due to aqueductal stenosis, they found a success rate of 81.9% in patients that received ETV/NCPC.[28]

Dandy-Walker complex is another condition treatable by ETV/NCPC, according to Warf´s Africa series.[26] Also in Uganda's scenario there was the largest series of this disease treated by neuroendoscopy. They concluded that this technique should be strongly considered as the primary management in place of the traditional standard of creating shunt dependence. For this disease, the success rate was 74% for Dandy-Walker malformation, 73% for Dandy-Walker variant, and 100% for mega cisterna magna. Eighty-eight percent of the cases were younger than 12 months and 95% had an open aqueduct at the time of ETV/NCPC. None required posterior fossa shunting in a mean follow-up of 24.2 months[26]. From the same African series by Dr. Warf, the use of the ETV/NCPC for communicating hydrocephalus is a viable option.[23]

It was significantly more successful than ETV alone in treating congenital idiopathic hydrocephalus of infancy. In this study with sixty-four infants (mean/median age, 6.1/5.0 months), sixteen consecutive patients were treated by ETV alone, and the subsequent 48 by ETV/NCPC (mean/median follow-up 34.4/36.0 months). ETV was successful in 20% and ETV/NCPC in 72.4 % at 4 years ($p<0.0002$, logrank test; $p=0.0006$, Gehan–Breslow–Wilcoxin); hazard ratio 6.9, 95 % CI 2.5–19.3. It was assumed that the primary effect of ETV, as a pulsation absorber, and of NCPC, as a pulsation reducer, might be to reduce the net force of intraventricular pulsations that produce ventricular expansion. On the other hand, ETV alone may be less successful for infants because of

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greater brain compliance. Regardless, this technique appears to have a higher long-term success rate and a lower infection rate than primary shunt placement and should be considered an effective primary treatment option for congenital idiopatic hydrocephalus. For multiloculated hydrocephalus, ablation of the choroid plexus in conjunction with septal fenestration and shunting was an option to control the hydrocephalus. Zuccaro and Ramos[31] reviewed their series of 93 cases with multiloculated hydrocephalus. Choroid plexectomy/fulguration was performed in 14 cases (eight by endoscopy and six by craniotomy). The authors concluded that each patient must be studied individually, because variable success rate.[30]

Initial experience with ETV/NCPC for post-hemorrhagic hydrocephalus of prematurity has revealed the importance of prepontine cistern status and the predictive value of FIESTA MRI imaging.[25] In hydrocephalus in premature infants with IVH and hydrocephalus ETV/NCPC is a safe initial procedure, obviating the need for a shunt in selected patients. Even though the success rate is low (37%), the lower rate of complications in comparison with shunt treatment may justify this procedure in the initial management of hydrocephalus. As several of the studied factors have shown influence on the outcome, patient selection based on these observations might increase the success rate[2]. Besides ETV/NCPC combined technique, nowadays there are new indications for isolated NCPC, such as in extreme hydrocephalus and hydranencephaly.[12,14,19] Avoidance of a CSF shunt is desirable in these conditions, since the thinness and fragility of their scalp, besides the common presence of infected scalp ulcers at the parietal bosses.

Morota and Fujiyama, in 2004[14], described the technique of unilateral transparietal approach for bilateral NCPC using a flexible neuroendoscope for three infants with IVH related hydrocephalus. Two of them were shunt independent. The authors suggested that the characteristics of favorable candidates for NCPC with severe advanced hydrocephalus like

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hydroanencephalic hydrocephalus, slow progressive hydrocephalus and lack of or thinned out septum pellucidum to make the bilateral endoscopic access possible. Malheiros et al., in 2010,[12] with a series of seventeen patients, have completed NCPC in 9 patients.

The procedure successfully controlled excessive head circumference and signs of increased intracranial pressure in 8 of these patients (88.8%). One endoscopic procedure in a hydranencephalic child failed after 7 months, resulting in VPS placement. Thus, of the 10 patients randomized to NCPC, 8 were treated successfully by NCPC (80%), and 2 went on to have a VPS. There were no complications related to this method of treatment.

So, the authors concluded that NCPC is an acceptable alternative to VPS for treatment of hydranencephaly and near hydranencephaly, because it is a single, definitive, safe, effective, and economical treatment that may avoid the complications of shunting. In another recent study,[19] in severe congenital hydrocephalus and hydranencephaly, NCPC stabilizes macrocephaly in approximately 40% of infants with and can be considered as an alternative to VPS placement.

Patients were followed from 30 to 608 days (median of 120 days). Of the 30 evaluable patients, NCPC was considered to be successful in 13 (43.3%), including 8 of 20 patients with severe hydrocephalus and 5 of 10 with hydranencephaly. Failure of NCPC was evident from increased head circumference in 14 (82%) of 17 patients and from CSF leakage in 3. Of the 17 failures, 13 occurred within 3 months of surgery. Six patients died: 3 whose NCPC procedures were failures, 2 whose NCPC was successful, and 1 postoperatively. Of the 17 in whom NCPC failed, 10 subsequently underwent VPS insertion This African study concluded that isolated NCPC stabilizes macrocephaly and can be considered as an alternative to shunt placement.[19]

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Conclusion

NCPC remains one of the options for the surgical treatment of pediatric hydrocephalus mainlyin communicating hydrocephalus, and this procedure might provide a temporary reduction in CSF production toallow the further development of CSF absorption. Adding NCPC to ETV for infants with hydrocephalus of various non-post infectious causes may increase independencyrelated to the shunt device. This result is very important for patients who are difficult to be followed up, due to geographical and socioeconomic constrains, as in developing countries. NCPC may also be an option for cases with high chance of shunt complication such as hydranencephaly and as an adjunct therapeutic measure for complex cases of hydrocephalus such as multiloculated hydrocephalus. Unfortunately, the long-term effects of coagulating about 80% of a child's choroid plexus and leaving larger ventricles, associated or not to ETV, are still unknown, especially in terms of neurocognitive aspects. However, it is a promising way to improve outcome of hydrocephalus, reducing shunt dependency, mainly in emerging countries. More studies with larger series are necessary to define the evident benefits of this technique.

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