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Use of Plasma Mediated Ablation in Pediatric Otorhinolaryngology

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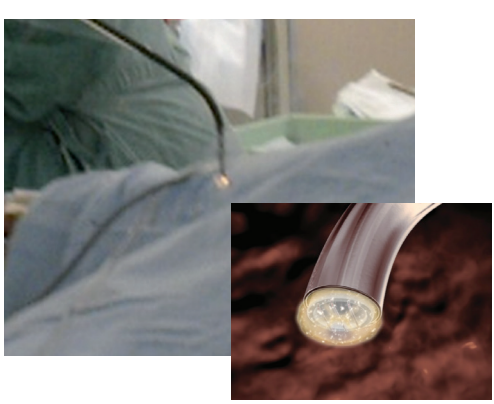
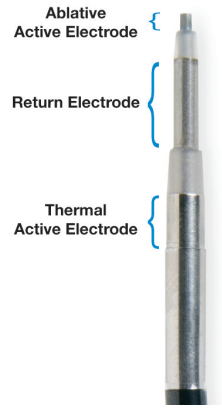
Introduction

Plasma Mediated Ablation (PMA) (cold ablation, cool ablation, Coblation™(CA), ionised field ablation, radiofrequency ablation or low-temperature plasma excision) is a recently introduced bipolar radiofrequency electrosurgery technique of tissue removal. The technique employs the dielectric barrier discharge principle[1], utilizing either a DC current or radiofrequency energy applied across a dielectric gas or fluid. The potential difference, between the active electrode and return electrode separated by a small gap over a nonconducting medium, at the tip of the instrument stresses the solution beyond its dielectric limit, causing electrical breakdown and with avalanching ionization, a field of plasma or localized ionized particles is created. At normal atmospheric pressures, a luminous plasma discharge is seen between the electrodes (**Figure 1**). Using isotonic saline, a plasma field of energetic sodium ions and released electrons has sufficient energy to break organic molecular bonds, resulting in-temperatures ranging from 40ºC to-160ºC, allowing molecular disassociation of the tissue, as compared to the temperatures of 400-600ºC as seen in other forms of electrosurgery[2]

Figure 1. Corona Glow or Plasma discharge by applying a flow of saline to the tip of the plasma electrodes.

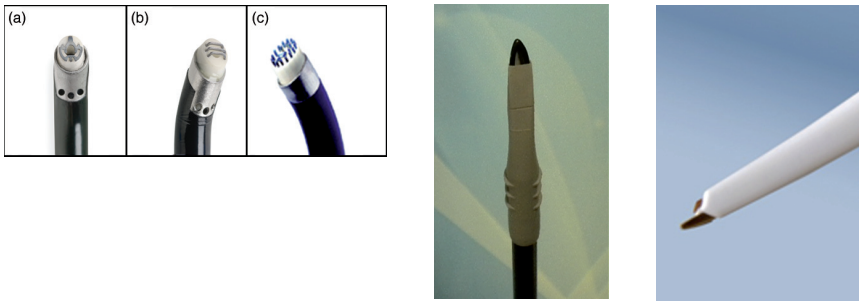




Though labelled cold ablation, the temperatures reached are not cold to the tissues it comes into contact, as it can cause steam to be produced. The term ‘cold’ refers to the percentage of ionised particles at that instant of time. However, the maximal thermal penetration is measured at less than 250 microns[2], hence the reported temperatures recorded away from the site of injury could be as low as 40ºC, and the risk of extensive damage to surrounding tissues is significantly

reduced whilst maintaining hemostasis. This is possibly one of its main advantages over the other technologies. Currently, there are a variety of delivery devices that purport to ustilise this technology, with a range of instruments to generate this localised plasma energy (**Figure 2**). PMA was popularized in otorhinolaryngology (ORL) for tonsillectomy and has since been used for a wide spectrum of otolaryngological procedures. In this chapter, we will specify the different applications of PMA in pediatric ORL, review the different studies published on its use and elaborate on advantages and disadvantages of each application.

Figure 2. Various devices that can generate "plasma" for use in otolayngology procedures



Adenotonsillectomy

Adenotonsillectomy (T&A) and tonsillectomy alone (TA) are by far the most used and studied surgical applications of PMA in pediatric ORL. The main indications for the performance of these surgeries in the pediatric populations are obstructive sleep apnea (OSA) and recurrent acute/chronic tonsillitis. PMA is becoming a more commonly used instrument for T&A and TA (16-27%).[3-4] Post-tonsillectomy hemorrhage (PTH), pain and timing of return to normal diet and activity are the major issues that contribute to the morbidity associated with tonsillectomy and had been looked into with regard to PMAuse in comparison to other surgical techniques.

Post TA and T&A hemorrhage, although infrequent, is a major concern that can harbor serious and even fatal outcome.[5] The post PMAtonsillectomy bleeding rate was assessed in various studies with controversial conclusions. Few studies showed lower PTH rate in the PMA group when compared to both classical cold steel dissection and electrocautery techniques,[6,7,8] while other studies showed no[9,10,11,12] and even higher[13,14,15] bleeding rate in the PMA group. Gallagher et al. compared PTH rate of 3 different techniques (Coblation, electrocautery and microdebrider) among more than 3000 children in a "real life" set up of different surgeons, both seniors and residents. A lower hemorrhage rate was found among the microdebrider group compared to the PMA and electrocautery groups (0.4%, 1.5% and 1.9%, respectively).[16] A recently published review[17] about PMA tonsillectomy, demonstrated primary and secondary hemorrhage rate of 1% and 2.3% among children (95% CI 0.3-2.1% and 1.1-4%), respectively. Of note are the different PTH rate definitions being used: any reported bleed by the child or family, blood seen in the oropharynx, blood loss that necessitates either control

in the operative theatre or blood transfusion etc. The aforementioned difference imposes important limitation on any conclusion about post-operative bleeding rate, whatever technique being used. Another interesting aspect was studied by Carney et al., who demonstrated a statistically significant learning curve with respect to both primary and secondary PMAPTH rates[18]. As for primary PTH, the learning curve, starting from more than 1% rate in the first procedure, reached a plateau of 0% after 30 procedures, while the secondary PTH rate was steadily decreasing from about 3% on the first fifty procedures to about 1% after conduction of more than 200 procedures (mean 2.1%). Divi et al. could not identify a learning curve with respect to PMAPTH rates.[19] Overall, after more than a decade of use, the expected PMAPTH rate benefit over other surgical techniques is still undetermined.

Postoperative pain remains a major morbidity after tonsillectomy and is an important reason for hospital readmission. It had been suggested that the use of PMA technique in tonsillectomy allows lower pain level in the postoperative period in comparison to both classical cold steel dissection and electrocautery techniques.[6,9,20-24] This advantage had been demonstrated mainly in the first 3 days following the surgery.[25,26] Nevertheless, other studies failed to show improved post-tonsillectomy pain levels with the use of PMA compared to other surgical techniques.[13,27] Altogether, It seems that post-tonsillectomy pain reduction is the most evident advantage of PMA use.

Timing of return to normal diet and activity after T&A or TA is an important aspect of post-operative morbidity and harbors financial implication due to delayed parental return to work, re-admission etc. All but one of the studies addressing this issue have shown faster return to normal diet and activity with PMAuse.[7,21,24,26,28-30] A formerly referred Cochrane database systemic review failed to find such a benefit with PMA use in Tonsillectomy.[13]

In addition, possible influence of PMA use on other well-known complications of T&A such as anesthetic and airway risks, aspiration, pulmonary edema, atlantoaxial subluxation, mandible fracture/dislocation, eustachian tube injury, nasopharyngeal stenosis, velopharyngeal insufficiency, and psychological trauma[31] was yet to be published.

Few published studies compared the cost of PMA tonsillectomy to other acceptable techniques and showed higher cost for PMA with respect to microdebrider[30] And both electrocautery and molecular resonance techniques.[32] A report published in November 2008 by a committee from McGill university, Montréal, Canada, looked into the cost effectiveness of preforming PMAtonsillectomy. They found that the cost of PMA, from the point view of the health center, is approximately $210 per child compared to $25 for electrocautery. The committee concluded that the small though measurable reduction in post-operative pain did not justify the additional cost. In conclusion, it seems that PMAuse does impose additional cost, which necessity needs to be evaluated individually for each case according to the patient and family, surgeon, institutional and health insurance provider preferences.

Lingual Tonsils and Tongue Base Surgeries

In the majority of pediatric cases, adenotonsillar hypertrophy is the cause of OSA with T&A or TA being the preferred method for surgical management. With the increased use of preoperative and postoperative polysomnography, it had been recognized that 10-20% of children will have persistent OSA following T&A with primary or secondary lingual tonsil hypertrophy as a major cause.[33] Sleep endoscopy for pediatric patients with sleep disordered breathing confirm that up to 85% of cases, the critical point of obstruction is at the tongue base [34].

A variety of techniques had been described in the literature for lingual tonsillectomy, including sharp dissection, laser techniques, suction diathermy, cryotherapy, and an ultrasonic coagulating dissector.[35] However, the traditional technique of lingual tonsillectomy has posed technical challenges due to difficult visualization access, postoperative morbidity and bleeding during tissue resection. The PMA instrument offers potential advantages with respect to hemostasis, safety and ease of use due to its curved shape. Lin and Koltai[33] have published their experience with 26 children who had persistent OSA after going through T&A. All the children had undergone endoscopic-assisted PMA lingual tonsillectomy and had been shown to have statistically significant reduction in the respiratory distress index postoperatively. No acute airway or hemorrhage issues were reported. Two patients had adhesions between the epiglottis and tongue base without any consequential airway or feeding problems. Pazos and Mair[35] had look into the complications of radiofrequency ablation in the treatment of sleep-disordered breathing, mainly in the adult population. With respect to 25 tongue base surgeries, they reported temporary tongue base neuralgia (4 cases), tongue base abscesses (2 cases) and floor of mouth edema with airway compromise (2 cases).

Another application was addressed by Maturo et al. with respect to their experience with treating OSA due to macroglossia.[37] They have conducted a submucosal minimally invasive lingual excision using PMA that resulted in significant clinical and polysomnographic improvement. Tongue base channeling as popularized by Zhang et al(38), has more recently been shown to be an effective and safe technique in inducing tongue base reduction with significant improvement in sleep study parameters. Overall, it seems that PMA use in lingual tonsil and tongue base surgeries is safe and effective alternative to other surgical techniques, but it is important to reassess the data over the next ten years to see if the results are maintained.

Oral Cavity Lymphatic Malformation Ablation

Lymphatic malformations (LM) of the oral cavity are less frequent than in other sites of the head and neck; within the oral cavity, the tongue is the most common site of presentation (**Figure 3**).[35] Patients with LM of the oral cavity experience recurrent infections, bleeding, swelling, and tenderness. Moreover, involvement of the tongue often causes dysphagia, dysarthria, or airway obstruction. Treatment goals for LM include providing a safe airway, reducing symptoms, correcting functional problems, and improving appearance.

Multiple alternative treatment modalities have been utilized for LM in the oral cavity, including steroid injection, electrocoagulation, carbon dioxide

laser excision and sclerotherapy, which has been shown to be quite successful in treating macrocystic lesions.[36] However, LM of the tongue are frequently microcystic, which are less amenable to sclerotherapy so conservative surgical excision is often advocated. Since complete resection of microcystic LM is rarely possible, PMA treatment targeted at reducing symptoms while causing as little damage as possible to adjacent tissue is rational.

Grimmer et al. have reported of 11 children with oral cavity microcystic LM involving the lips, tongue, floor of the mouth, or buccal mucosa treated with PMA.[41] The majority of children were able to tolerate oral intake in the recovery room. Four patients (36%) resumed regular activities within a day; 5 (45%), within a week; and 2 (18%), within 2 weeks. All patients related diminished bleeding, pain, infection, or vesicle formation post-operatively, with more than half reporting a significant improvement (6 patients) or complete resolution (1 patient). Other case series of PMA treatment of tongue LM in children had found it to be safe technique with minimal post-operative pain and significant symptomatic improvement.[42,43] Overall, although little published data, PMA treatment of oral cavity microcystic LM, seems like a good and safe management modality whose main advantage, similar to PMA tonsillectomies, is reduced post-operative pain and discomfort.

Figure 3. Microcystic lymphatic malformation before and after plasma mediated ablation with minimal morbidity, along with the plasma wand in action

Inferior Turbinate Reduction

Several studies in adults have confirmed that PMA inferior turbinate reduction (ITR) is an effective procedure for inferior turbinate hypertrophy with benefits that persist for at least 6 months after surgery.[44-46] In children, the procedure is frequently performed at the time of another procedure such as T&A or FESS. As such, it is difficult to assess the additional efficacy of ITR alone. Adding turbinate reduction leads to a minimal increase in surgical time and no noticeable increase in postoperative morbidity and as such has gained popularity. Jiang et al. have published a questioners based study among pediatric otolaryngologists and found that the most common indication for pediatric ITR is nasal obstruction (82%), followed by sleep disordered breathing (16%), and that PMA was the most popular single technique being used (47%).[47] Simeon and colleagues[48] investigated the efficacy of PMA ITR on nine children with allergic rhinitis. In this study, assessment consisted of rhinomanometry, visual analog

scales, and quality of life questionnaires. Favorable and statistically significant decreases in binasal resistance, pruritus, sneezing, hyposmia, and rhinorrhea were observed and sustained at 6-month follow-up. The authors noted that PMA turbinoplasty did not abolish rhinitis but rather assisted in the efficacy of topical corticosteroids. Overall, PMA has shown promising results with respect to ITR. The procedure is effective, well tolerated with minimal adverse effects. The main disadvantage of PMA technology relates to a lack of well planned, double-blind, placebo-controlled randomized trials to better elucidate causal relationships.

Juvenile Nasopharyngeal Angiofibroma Resection

Juvenile nasopharyngeal angiofibroma (JNA) is a highly vascular, progressively invasive, benign tumor arising almost exclusively in adolescent males. Surgical resection is the standard treatment, with favorable endoscopic approach in mild to moderate stages. A recently published study looked into the treatment of three adolescent boys with JNA (up to Radkowski stage IIC) using PMA assisted technique.[49] All the patients underwent complete resection with acceptable intra-operative blood loss.

None of the patients required post-operative blood transfusion, nasal packing, or hospitalization of greater than one day. Follow-up showed no complications and no recurrence. Zhang et al., in their case series of 4 JNA patients treated with PMA, reported of similar findings.[50] Another study compared PMA assisted technique to classical endoscopic approach in the treatment of early stage (Fisch class I) JNA.[47] Both techniques had been found to be safe and effective in achieving complete resection. PMA was significantly better with respect to operative time and intra-operative blood loss, which arise as the two main advantages of PMAJNA resection in previously mentioned studies.[49-50]

Recurrent Respiratory Papillomatosis Resection

Recurrent respiratory papillomatosis (RRP) is the most common benign neoplasm of the larynx that affects approximately 4.3 per 100 000 children in the USA.[52] Various medical (anti-viral application) and surgical modalities (cold steel dissection, suction diathermy, CO_2 lasers, and microdebrider) have been used to treat RRP[49], but evidence-based studies comparing treatments are lacking.[52] PMA use for RRP resection may offer better control of both collateral tissue damage and intraoperative bleeding. Only two publications had been found on PMA use for RRP, both for adult patients, but since RRP is mainly a pediatric disease, both will be discussed. Timms et al. reported of two patients with RRP previously treated with cold steel and laser techniques, who subsequently underwent PMA.[54] The authors described good control of disease, with minimal scarring and preservation of the mucosal wave at six months. They also reported that PMA afforded the advantage of a bloodless field with minimal surrounding tissue damage. In 2010, Carney et al. have reported of 6 patients with RRP treated with PMA after failure of at least two years treatment by CO_2 laser vaporisation with or without intralesional Cidofovir.[55] In half of the patients PMA use resulted in significant (>50%) longer periods between interventions. The authors emphasized the need for PMA probes designed for laryngotracheal use – which are in continuous process of development. The long term advantage of PMA use for RRP with

respect to recurrence and post-operative scaring is yet to be studied, especially in the pediatric population.

Suprastomal Tracheal Granuloma Removal

Suprastomal granuloma formation is a common complication of pediatric tracheotomy. The lesion should be resected if it is significantly obstructive. High recurrence rate is expected with various surgical techniques. Kitsko et al. have reported of 4 pediatric patients treated with PMA excision of suprastomal granulomas which has shown to be a safe and effective procedure with several advantages over traditional methods.[56] These include eliminating risk of tissue loss into the distal airway, decreased risk of bleeding, and overall ease of use. All the procedures seemed effective but no long term outcome had been reported. In addition, another likely advantage of laryngotracheal PMA use, especially over laser techniques, is the reduced risk of airway fire induction, as the technique should not cause solid plastic or tissues to ignite.[57]

Summary

Plasma mediated ablation is a relatively new technique with a various applications in pediatric ORL. It is part of a burgeoning field of plasma medicine. Most of the studies of PMA use in pediatric ORL are of low evidence level and offer no data about long term outcome. It is technically an exciting new tool for the management of soft tissues, and has a role in removing tissues without causing significant collateral damage. This is supported by the senior author's own experience with the technology to date. Future studies will need to address those issues and allow better understanding of the advantages, limitations and necessary developments of PMA in the different fields of pediatric ORL.

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