Bone Wax in Neurosurgery: A Review

Joe M. Das

Key words
- Bone
- Bone wax
- Hemostasis
- Neurosurgery
- Review literature
- Waxes

Abbreviations and Acronyms
- BW: Bone wax
- PEG-PPG-PEG: Polyethylene glycol—polypropylene glycol—polyethylene glycol

INTRODUCTION

Bone wax (BW) is a widely used hemostatic agent in both cranial and spinal surgeries. It is mesmerizing to watch the heavy gush of blood from a diploic vein during a craniotomy being controlled by the prompt application of BW. Frequently, however, BW is used unnecessarily to control minute bone bleeding. Thus, a question has been raised in several specialties and surgeries, especially spine surgeries: Is the use of BW really indicated? This question is important because the use of BW has been associated with numerous complications, especially defective bone healing. Hence, many other alternatives are being developed and tried. We aim to review all the characteristics, uses, and complications associated with the use of BW, especially in relation to neurosurgery.

HISTORY

Henri-Ferdinand Dolbeau (1830–1877), the Professor of External Pathology and Surgeon of Paris Hospitals, was the first person to use BW for neurosurgery. He was the first surgeon to extirpate a frontal osteoma and use BW for the same in 1864. For experimental purposes in closing the venous sinuses, even Magendie (1783–1855) had used BW previously. It has been documented that unadulterated beeswax was used for amputation stump hemostasis during the American Civil War (1861–1865). Sir Victor Alexander Haden Horsley (1857–1916) popularized the use of BW as a hemostatic agent after experimenting on cranial bones of dogs in 1885. He modified his preparation of BW with the help of an Oxford Street pharmacist named P.W. Squire, as the original one was not meeting the standard of modeling wax. The first documented use of this modified BW was by Rushton Parker, who reported its use in cranio-cervical surgery in 1892 for chronic suppurative otitis media with sigmoid sinus and jugular vein thrombosis. Since this period, the term Horsley’s wax remained synonymous with BW, although several modifications in its composition occurred over 125 years. Many Russian neurosurgeons argue that the formulation was developed and introduced into neurosurgery as early as the 1850s by surgeons in Moscow. In addition, some hospitals in Russia continue to prepare beeswax according to the original nineteenth-century formula.

It has been 125 years since the so-called initial use of bone wax (BW) by Sir Victor Horsley, and a review of this age-old hemostatic agent seems appropriate. The first use of BW for hemostasis occurred in the eighteenth century, when modeling or candle wax was used for hemostasis. Although the pioneers in the use of BW in craniofacial surgeries were Jean Louis Belloq, Kristian Kristianovich Salomon, and François Magendie, the first successful use in neurosurgery was demonstrated by Henri Ferdinand Dolbeau in 1864 after extirpation of a frontal osteoma. This technique was further popularized by Sir Victor Alexander Haden Horsley, the father of British neurosurgery, who is often incorrectly mentioned as the inventor of BW. Originally derived from beeswax, the currently available commercial preparation also contains paraffin wax and isopropyl palmitate. The main action being mechanical tamponade, BW has found several other uses in neurosurgery, other than being a hemostatic agent. Although it is cost-effective, the use of BW is associated with several complications also, including ineffective bone healing and infection. Several alternatives are being developed, but none are yet a full replacement for “Horsley’s wax.”

COMPOSITION AND INGREDIENTS

Beeswax (cera alba; melting point = 60°C), the main ingredient of BW, is secreted by wax glands of worker bees of the genus Apis and is used in the construction of hive. Chemically, BW comprises waxlike polyester oligomers of lower hydroxy carboxylic acids that range from viscous fluids to solids at room temperature.

BW is a sterile mixture of 85%–90% white beeswax and 10%–15% isopropyl palmitate, a palm oil-based emollient, moisturizer, and thickening and antistatic agent used as a wax solvent.
<table>
<thead>
<tr>
<th>Product</th>
<th>Composition</th>
<th>Advantages over Bone Wax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ostene or AOC bone wax&lt;sup&gt;35&lt;/sup&gt;</td>
<td>Water-soluble alkylene oxide copolymers derived from ethylene and propylene oxide</td>
<td>• Inert&lt;br&gt;• Not metabolized; eliminated from the body over time&lt;br&gt;• Decreased rates of infection and tissue reaction</td>
</tr>
<tr>
<td>Hemosorb&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Mixture of calcium stearate, vitamin E acetate, and liquid surfactant</td>
<td>• Absorbable (within 30 days)&lt;br&gt;• Spreads easily with minimal adhesion to gloves&lt;br&gt;• Biocompatible&lt;br&gt;• Allows strong bone adhesion&lt;br&gt;• Water resistant&lt;br&gt;• Requires no kneading</td>
</tr>
<tr>
<td>Surgifoam&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Absorbable porcine gelatin sponge composed of a sodium chloride solution from oxidized regenerated cellulose</td>
<td>• Rapid hemostasis&lt;br&gt;• Large absorbing ability&lt;br&gt;• Water soluble&lt;br&gt;• Malleable for ease of handling</td>
</tr>
<tr>
<td>Bioactive glass/chitosan/carboxymethyl cellulose composite scaffold&lt;sup&gt;37&lt;/sup&gt;</td>
<td></td>
<td>• Excellent biocompatibility&lt;br&gt;• No cytotoxicity&lt;br&gt;• Dominant role in bone regeneration and hemostasis</td>
</tr>
<tr>
<td>PEG-PPG-PEG copolymer mixtures and pregelatinized starch</td>
<td>Resorbed within 2 days&lt;br&gt;• As effective as the commercial bone wax in hemostasis&lt;br&gt;• Better adherence to the bone surface&lt;br&gt;• The incorporation of pre-gelatinized starch further helps in improved molding texture and decreased glove adherence&lt;br&gt;• Does not inhibit the osteogenesis</td>
<td></td>
</tr>
<tr>
<td>Absele&lt;sup&gt;39&lt;/sup&gt;</td>
<td>Stabilized fibrin and soluble collagen</td>
<td>• Absorbed totally within 3 weeks&lt;br&gt;• Minimal tissue reaction</td>
</tr>
<tr>
<td>Calcium phosphate cement&lt;sup&gt;40&lt;/sup&gt;</td>
<td>Hydrophilic polyethylene glycol and hydroxyapatite</td>
<td>• Self-setting&lt;br&gt;• Mechanical performance is comparable to that of cancellous bone</td>
</tr>
<tr>
<td>Auto suture bone wax&lt;sup&gt;41&lt;/sup&gt;</td>
<td>Mixture of glycolide, caprolactone, mannitol and G-tricalcium phosphate</td>
<td></td>
</tr>
<tr>
<td>Gelatin based bone wax&lt;sup&gt;42&lt;/sup&gt;</td>
<td>Gelatin powder added to rifamycin</td>
<td>• Better sternal wound healing after cardiac surgery</td>
</tr>
<tr>
<td>Microporous polysaccharide hemospheres&lt;sup&gt;43&lt;/sup&gt;</td>
<td></td>
<td>• Not detected in postoperative imaging as early as day 1&lt;br&gt;• No tumor-mimicking contrast enhancement.&lt;br&gt;• Do not inhibit bone healing</td>
</tr>
<tr>
<td>Polyethylene glycol/microfibrillar collagen&lt;sup&gt;44&lt;/sup&gt;</td>
<td></td>
<td>• Excellent bony hemostasis&lt;br&gt;• Does not inhibit bone growth</td>
</tr>
<tr>
<td>Pluronic implants&lt;sup&gt;45&lt;/sup&gt;</td>
<td>90% Pluronic P85/10% Pluronic F88</td>
<td>• Handling properties similar to those of bone wax&lt;br&gt;• Readily achieves hemostasis&lt;br&gt;• Does not inhibit bone regrowth</td>
</tr>
<tr>
<td>OsteoStat&lt;sup&gt;46&lt;/sup&gt;</td>
<td>Hydroxyapatite and biodegradable poly-lactic acid</td>
<td>• Higher amount of bone growth&lt;br&gt;• Easily sterilized&lt;br&gt;• Biocompatible&lt;br&gt;• Immunogenic and allergen free, as it does not contain biological components</td>
</tr>
</tbody>
</table>

Continues
tissue, and a lack of bone formation.13

An inflammatory reaction to BW: 1) a brous reaction, 2) a foreign-body reaction characterized by giant cells, plasma cells, and 3) a marked foreign-body reaction, and 3) a marked foreign-body reaction, which was resorbed and caused only a minor inflammatory reaction.16

MECHANISM OF ACTION AND CHEMICAL PROPERTIES

BW coats the bleeding bone surfaces and forms mechanical tamponade for the blood to ooze out. The hemostatic effect of BW is based on its physical properties; it acts as a tamponade by stopping the blood flow from damaged vessels in the trabecular bone and thereby facilitates clot formation.

Optimum working temperature is 70°—74°F (21°—23°C).12 BW should be used immediately after removal from the package. Using aseptic technique, BW should be warmed to the desired consistency by manipulation with the fingers or by immersion of the unopened foil packet in a warm, sterile solution. It can be applied with fingers or the tip of the dissector; if left in situ after use, it is better to remove the excess. BW is neither absorbed nor metabolized.

Alberius et al.12 used a rat calvarial bone model to identify the 3 stages of inflammatory reaction to BW: 1) a nonspecific inflammatory response, 2) a foreign body reaction, and 3) a marked fibrous reaction. The observations are consistent with histologic findings associated with the implantation of BW in a rat tibia model, which typically include foreign-body reactions characterized by giant cells, plasma cells, fibrous tissue, and a lack of bone formation.13

HISTORICAL VARIANTS

The original Horsley’s wax (antiseptic wax) as used by Rushton Parker was composed of 7 parts beeswax, 1 part almond oil, and 1% salicylic acid.4

Moorhof’s BW (iodoform BW) was invented by Moseti-Moorhof in 1903 and was used in the treatment of chronic osteomyelitis with bone abscess. Equal parts of spermaceti and sesame oil were sterilized in a water bath, and later 60 parts of this was mixed with 40 parts of iodoform. This mixture resulted in a yellowish, brittle Moorhof’s BW, melting at approximately 50°C. Before using, it was heated to just above the melting point and kept constantly stirred to prevent iodoform from settling to the bottom of the flask.23 Moore modified Moorhof’s BW with 1% iodine, 2 parts olive oil, and 8 parts spermaceti as ingredients. At first, spermaceti and olive oil were mixed in a water bath and heated. Iodine was added later, and heating was stopped. The mass became solid at body temperature.23

Another historical alternative was Beck’s bismuth emulsion, which consisted of bismuth subnitrate (30 g), white wax (5 g), and petroleum jelly (60 g).43

Geary and Frantz’s carbowax was invented in 1950, and it consisted of oxidized cellulose as the active component and a mixture of high-molecular-weight resorbable polyethylene glycols as vehicles to deliver it. Instead of beeswax, they used 60% carbowax, 15% polyethylene glycol, and 25% oxidized cellulose. They compared their material to original BW in a rib fracture model. Polyethylene glycol was resorbed and caused only a minor inflammatory reaction.40

USES OF BW IN NEUROSURGERY

Although BW is used mainly in neurosurgery for attaining hemostasis of oozing bone surfaces and to control bleeding from emissary and diploic veins, it has several other uses. One use is to prevent cerebrospinal fluid leakage following skull base repair, such as anterior cranial fossa repair, by applying across the bony defect. Sometimes during craniotomy and temporal bone nibbling, the middle meningeal artery can become torn and the stump can retract into the foramen spinosum, producing heavy bleeding. In such cases, BW can be applied across the foramen to plug it, producing rapid hemostasis, which can be life-saving. During drilling of skull, BW can be applied over the surrounding tissues and act as a protective covering against the blades of the drill.

During spine surgeries, it is common to see the screws falling down from screwdrivers because of the lack of a proper grip. If such a technical problem occurs, BW can be applied to the tip of the screwdriver to adhere the screw to it.17 Other well-known uses for BW in spine surgery are to attain hemostasis after removal of distraction pins during anterior cervical spine surgery, following vertebral artery injury after placement of cervical spine screws,45 and as a marker for spatial orientation in intraoperative magnetic resonance imaging.22

BW can also be used as a template for intraoperative evaluation of craniofacial defects and shaping of polyethylene implants for covering the same.46 If a cavernous carotid aneurysm exhibits repeated or massive epistaxis, sphenoid sinus packing with BW can be done as a temporary measure to control the epistaxis.22

Table 1. Continued

<table>
<thead>
<tr>
<th>Product</th>
<th>Composition</th>
<th>Advantages over Bone Wax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancomycin cream</td>
<td>Vancomycin</td>
<td>Prevents infection</td>
</tr>
<tr>
<td>Hydroxyapatite, chitosan and starch</td>
<td></td>
<td>Excellent biocompatibility</td>
</tr>
<tr>
<td>Monopolar electrocautery</td>
<td></td>
<td>Mechanical stability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antibacterial property</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Useful for small bone bleeders</td>
</tr>
</tbody>
</table>

AOC, alkylene oxide copolymer.
and granuloma; inflammation and infection; interference with bone healing; cord compression leading to neurological deficits, including quadriplegia; osteohypertrophy; venous sinus thrombosis; soft tissue sarcomas following retained BW; migration into the sigmoid sinus, into the parenchyma, and outside through the wounds; and ptosis and diplopia.

**ADVANTAGES AND DISADVANTAGES**

Bone wax is cost effective (with one plate costing around $10) and acts immediately, but its use can result in infection because it diminishes the ability of bone to clear bacteria. As it interferes with bone healing, its use should be restricted in sites where fusion is desired, especially in spine surgeries. It should not be used within the spinal canal, as it can lead to neurologic deficits.

**AVAILABILITY AND PACKAGING**

Bone wax has a white to off-white color with a specific gravity of 0.95. It is sterilized by gamma radiation and should not be stored in areas warmer than 77°F (25°C). It has a shelf life of approximately 5 years if stored properly, and it is usually available commercially as plates or sticks weighing 2.5 g per pack.

**ALTERNATIVES AND IMPROVISATIONS**

There is a wide range of hemostats for use in neurosurgery. BW has undergone several modifications, and alternatives have been devised over the ages, although none have been found to beat this age-old hemostat.

At least 16 agents have been described in the literature (Table 1) that are being used as alternatives to BW. Some of these agents are in the experimental phase, and others are being used in specialties such as orthopedics and cardiac surgery. Many of these agents are claimed to be superior to BW, although none of them have been able to replace it. Ostene (Ceremed, Inc., Los Angeles, California, USA), Hemasorb (Abyrx, Inc., Irvington, New York, USA), and Surgifoam (Ethicon, Inc., Somerville, New Jersey, USA) are the most commonly used alternatives. Pluronics are tri-block copolymers, consisting of a hydrophobic polypropylene oxide unit in between 2 basic hydrophilic units of polyethylene oxide, with the basic sequence of an A–B–A structure. Absorbable agents include Hemasorb, polyethylene glycol–polypropylene glycol–polyethylene glycol (PEG-PPG-PEG) copolymer mixtures, and Absele (Ethnor, Division of Ethicon, Inc., Edinburgh, UK). Agents that do not impair bone healing include bioactive glass/chitosan/carboxymethyl cellulose composite scaffold, PEG-PPG-PEG copolymer mixtures, microporous polysaccharide hemispheres, polyethylene glycol/microfibrillar collagen, pluronic implants, and OsteoStat. Hemasorb, Surgifoam, PEG-PPG-PEG copolymer mixtures, and similar pluronic implants have the advantage of ease of handling and decreased adhesion to surgical gloves during usage. Hemasorb, bioactive glass/chitosan/carboxymethyl cellulose composite scaffold, OsteoStat, and hydroxyapatite/chitosan/starch are absolutely biocompatible with almost no allergic reaction. There is a reduced chance of infection because of some antibacterial properties following the use of Ostene, gelatin-based bone wax, vancomycin cream, and hydroxyapatite/chitosan/starch complex.

Some newer local hemostatic agents include FloSeal (Baxter International, Inc., Deerfield, Illinois, USA) and Surgifoam (Ethicon, Inc., Somerville, New Jersey, USA) hemostatic matrix. They are composed of a granular gelatin matrix derived from collagen cross-linked with glutaraldehyde. FloSeal is made of a matrix of bovine gelatin and human thrombin with a preparation time of approximately 68 seconds, and it is reabsorbed by the body in 6–8 weeks. Surgifoam hemostatic matrix is composed of porcine gelatin and human thrombin. Its preparation time is approximately 81 seconds, and reabsorption time is 4–6 weeks. Both of them can be used at their best to control diffuse capillary oozing from the epidural space or from the resected tumor cavity. It is natural to have doubts as to whether these agents can act as alternatives to the antique BW; however, the safety and effectiveness of these agents, for use in neurosurgical procedures, have not been established through randomized clinical studies. A study comparing both agents in spine surgeries did not show any differences in terms of efficacy and ease of use or their effectiveness in bleeding control. Neither of these agents is to be used as a substitute for conventional procedures for hemostasis, including BW. Moreover, both agents are associated with thrombotic complications, especially when used in the presence of bleeding from bone spongiosa.

**CONCLUSION**

Despite BW being useful in controlling massive bone bleeding and being the only hemostat of choice in certain situations, its use is limited by several complications. The following recommendations can be proposed regarding the use of BW in neurosurgery. It can be used in massive bleeding from diploic veins during cranial surgery, just at the site of bleeding. The use of BW in a large quantity is, however, not recommended. Its use is desirable if the patient is having coagulopathy. It is better to restrict its use in spine surgery, where fusion is desired. BW alternatives can be used instead. For minor bleeding from the bone surface or edges during craniotomy, monopolar cautery at a high amperage setting is a good, cost-effective alternative. Some agents have been recently marketed, claiming to overcome one of the disadvantages of bone wax—impaired bone healing. Additional trials are needed to validate the efficacy of these agents versus BW.

**REFERENCES**


