Spray-Irrigation System Attached to High-Speed Drills for Simultaneous Prevention of Local Heating and Preservation of a Clear Operative Field in Spinal Surgery

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Abstract

Heat generation due to drilling during spinal surgery is potentially hazardous to nerves. Saline irrigation is often performed to prevent such local heating, but sometimes floods and obscures the operative field. We have developed a spray-irrigation system for attachment to high-speed drills, which sprays saline solution with an air-jet in the direction of the surface cut by the drill. We anticipated that this air jet would create a clearer operative view by displacing excess fluid, and would also provide an added cooling effect greater than that of irrigation with saline. This study was designed to evaluate these predicted effects of the spray-irrigation system compared to conventional irrigation. A thermography study was performed to confirm the cooling effect of the spray-irrigation system. A plaster board coated with adhesives was drilled at 100,000 rpm along a 10-cm line for a duration of 20 seconds. Thermograms were recorded every minute, without cooling, with irrigation, and with the spray-irrigation system. To examine the operative views, continuous drilling for a period of seconds was performed with conventional irrigation and with the spray-irrigation system. Local heating was inhibited by the spray-irrigation system to 14–30% of that with irrigation. A clear operative field was maintained during continuous drilling using the spray-irrigation system through the air-jet action of the system. The spray-irrigation system can simultaneously provide effective cooling and a clear operative field during surgical manipulations with high-speed drills.

Key words: spinal surgery, high-speed drill, inhibition of thermal elevation, clear operative view, heat injury

Introduction

High-speed drills are frequently utilized for bone cutting in modern spinal surgery. High-speed drills can remove bone tissue faster than conventional drills, with the disadvantage that greater heat is generated in the tissues. To prevent heat conduction to the surrounding tissue, some manufacturers provide irrigation systems attached to high-speed drills. Use of an adequate quantity of saline can provide sufficient cooling, but often soaks and obscures the operative field. To resolve this problem, we have developed a spray-irrigation system to be attached to high-speed drills. This system sprays saline with an air-jet in the direction of the surface of the tissue cut by the drill. The present experimental results show the potential of this system as an effective method for cooling tissue undergoing drilling, while preserving a clear operative field.

Materials and Methods

A two-layer cylindrical guide tube was designed to supply saline through the inner tube and an air-jet through the outer tube (Fig. 1). This guide tube can be attached to drill guides to spray saline directly onto the tissue surface in contact with the drill.

A study was performed to confirm the inhibition of local heating with the spray-irrigation system compared to a conventional irrigation method. Heat generation is influenced by the conditions of drilling and the properties of the bone material.1,3) Real bone material was considered unsuitable for this experiment because of its heterogeneous properties, so homogeneous plaster boards were used as drilling
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Fig. 1 Photographs of the two-layer cylindrical guide tube for the spray-irrigation system, supplying saline through the inner tube (arrow) and an air-jet through the outer tube (arrowheads).

Fig. 2 Photograph showing the thermography experiment. A plaster board coated with adhesives (arrowheads) on the surface was cut with the high-speed drill along a 10 cm line for 20 seconds. The plaster board and the drill were fixed on an electric slider (arrow) to maintain a fixed contact pressure. Thermograms were recorded every second.

Substrates, and stable drilling pressures were maintained at the surface of the material with a special device (Fig. 2). A 5-mm thick plaster board coated with adhesives on the surface was made with a Z printer 310 (Z Corporation, Burlington, Mass., U.S.A.). The plaster board was cut with a 5-mm steel burr or 5-mm diamond burr attached to a high-speed drill (Sommet High Speed Motor System; Muranaka Medical Device Cooperation, Osaka) at a maximum speed of 100,000 rpm. To maintain a fixed contact pressure, the drill and the plaster board were fixed on an electric slider (Oriental Motor Cooperation, Tokyo), which moved the plaster board linearly at a speed of 5 mm/sec. The two-layer cylindrical guide tube was attached to the drill and directed at the drill tip, supplying water and/or an air-jet to the drilling surface. Thermograms were recorded every second for 20 seconds using an NEC TH3100mR unit (NEC Corporation, Tokyo), without cooling, with only irrigation, and with the spray-irrigation system. Conventional irrigation was performed with room-temperature saline at 16 ml/min, and spray-irrigation used saline irrigation at 16 ml/min, and an air-jet at a pressure of 0.2 MPa. Quantitative analysis measured areas at temperatures of over 37.7°C using ImageJ 1.42 (http://rsbweb.nih.gov/ij).

In a separate study, operative views of a lumbar laminectomy performed in one patient were observed with conventional irrigation and with spray-irrigation. Irrigation was performed with room-temperature saline at 12.5 ml/min for both conventional irrigation and the spray-irrigation system, and the air-jet of the spray irrigation was sterilized with a micro filter, and supplied at 0.2 MPa.

Results

The thermograms demonstrated that local heating was markedly inhibited by the spray-irrigation system (Fig. 3). As the duration of continuous drilling was prolonged, the efficacy of spray-irrigation for the prevention of local heating became more apparent. Heat conduction was inhibited in all directions from the drilling point by the spray-irrigation system, whereas marked local heating was observed behind the drilling point with conventional irrigation. The time courses of the drilling areas using a steel burr and a diamond burr are shown in Fig. 4. Without cooling, the area over 37.7°C gradually increased during continuous drilling. The area of heating using a 5-mm diamond burr could not be measured correctly without cooling after 17 seconds, because the measured area exceeded the range of the thermogram. The area of heating increased within the initial 8 seconds using conventional irrigation, but remained stable thereafter. In contrast, spray-irrigation inhibited local heating immediately after the start of drilling. Comparing data 9 seconds after drilling initiation, local heating was inhibited by the spray-irrigation system to 14–30% of the area with conventional irrigation (14–18% in the experiments with a steel-burr and 21–30% in the experiments with a diamond burr).

The operative view of a lumbar laminectomy demonstrated that the spray-irrigation system displaced blood and fluid from the cutting surface of the bone, resulting in a constantly clear operative view during continuous drilling (Fig. 5A). Without the air-jet, the view of the cutting surface was inter-
mittently obscured by fluid, and adequate suction was essential to keep the field clear (Fig. 5B).

**Discussion**

Heat injury to spinal nerves may be induced by the use of high-speed drills during spinal surgery. Experimental studies have shown that local heating may disturb the motor and sensory functions of nerve roots and sciatic nerves. Various irrigation systems are now available for high-speed drills, but experimental studies have shown that temperatures can still be elevated to hazardous levels, even if the operative surfaces are cooled by irrigation. In addition, cooling with irrigation during the operative procedure introduces the problem of soaking and obscuring of the operative field by the quantities of saline solution necessary to adequately inhibit local heating. Therefore, levels of irrigation are likely to be limited by the need for a clear operative view, resulting in loss of the cooling effect.

The new spray-irrigation system was designed to preserve a clear operative view during drilling, and to simultaneously provide improved cooling efficiency compared to conventional irrigation methods. We anticipated that the air-jet would blow...
out the fluid from the operative field and provide additional cooling, thus surpassing conventional irrigation methods. The present study suggests that the spray-irrigation system works as predicted. Thermography revealed that the spray-irrigation system markedly inhibited local heating during continuous drilling more effectively and more immediately than conventional irrigation. In contrast, marked heating was observed behind the drilling point with no cooling and with conventional irrigation, whereas heating was inhibited in all directions from the drilling point by the spray-irrigation system (Fig. 3). As a result, the total area heated to over 37.7°C was reduced by the spray-irrigation system to 14–30% of the area with conventional irrigation (Fig. 4). These results suggest that the spray-irrigation system prevented heat conduction from the drilling point. The spray-irrigation system cools the area inside the spray-irrigation angle, which includes not only the drilling point but also the surrounding area, resulting in marked inhibition of thermal conduction. Furthermore, the operative view of a lumbar laminectomy was clearer than with conventional irrigation, because the spray-irrigation system displaced the solution from the drilling surface (Fig. 5A). In contrast, the operative field was flooded with fluid and obscured by suction techniques when cooled only by conventional irrigation (Fig. 5B). These results suggest that spray-irrigation facilitates more desirable conditions for surgical manipulation with high-speed drills when compared with conventional irrigation.

The spray-irrigation system can be applied to any type of surgery requiring bone removal with high-speed drills if the rate of irrigation and the pressure of the air-jet are set at appropriate levels.

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References


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