Acoustic Liver Cauterization: A Potential Tool for Bloodless Surgery

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Abstract: A technique was investigated of resectioning liver which would minimize blood loss. High intensity focused ultrasound was employed to volume cauterize the border regions of liver tissue that were to be later excised. The purpose was to pre-cauterize before cutting the tissue thus avoiding blood loss. The method was applied to anesthetized rabbits (4) and pigs (3). After pre-cauterizing and then resectioning the tissue, bleeding only occurred in vessels larger than 2 mm. No oozing occurred from the liver parenchyma when completely treated. The method offers major surgical advantages.

INTRODUCTION

Liver surgery is hampered by the difficulty in controlling hemorrhage, particularly the slow oozing from injured hepatic surfaces. Electrocautery, the time tested tool for other tissues, fails in treating liver parenchyma. Surface charring occurs while oozing continues from under the crusted surface. Other techniques include blunt dissection, Nd-YAG laser, an ultrasonic surgical aspirator (1) and more recently an ultrasonic scalpel (2). With the laser some of the same charring problems of electrocautery occur. The ultrasound aspirator using ultrasound at 23 KHz, fragments the softer tissue which are aspirated from the site leaving vessels to be ligated before cutting. No cauterizing effect has been assigned to its vibrating action. This method, along with blunt dissection, is time consuming and leaves the parenchyma in a state where it tends to ooze. More recently, a higher frequency ultrasonic device (55 KHz) with a special hook type probe has been found to have a cauterizing effect by the heat produced from the friction of the vibrating tip. The device has been reported to be able to cauterize vessels without difficulty, which are 2 mm or less. However, all of these methods function on the surface of the tissue. For transecting tissue, they have to be applied in a step by step manner to cut through the tissue or to cauterize after each incision. On the other hand, high intensity focused ultrasound (HIFU) can penetrate to a depth in tissue and produce coagulative necrosis there without requiring the removal of the intervening tissue.

We have successfully stopped bleeding from incisions made in animal livers using (HIFU) operating at frequencies of 3.3 MHz (3). The action involved cauterizing a volume of tissue along the surface of the incision by generating heat due to the absorption of the high intensity ultrasound. The question arose: Could we avoid bleeding during surgery by pre-cauterizing a thick surface around a region to be resected, prior to the actual dissecting of it? For example, by isolating the region from the blood supply with a coagulated sheet of tissue, we hypothesis little blood would be lost during the cutting and removal of the tissue of concern. We report early tests of this theory.

METHODS AND RESULTS

The livers of anesthetized rabbits (4) and pigs (3) were treated in this manner under a protocol approved for animal studies at the University of Washington. Two HIFU transducers (3.3 and 3.5 MHz focused at 3.5 and 5.5 cm, respectively) were used. The electronic drive system consisted of a digital function generator (Model 33120A, Hewlett Packard, Palo Alto, CA.) coupled through a footswitch control to a RF power amplifier (Model AP400A, ENI, Rochester, NY) which in turn connected to a matching network and then the ultrasound transducer. We submerged the abdomen of the rabbits in our initial work in order to couple the ultrasound from the transducer to the surgically exposed liver. In later work, we developed a method of coupling energy from the transducer to the tissue through a water filled cone. A thin polyethylene membrane (13 microns) was located over the tip of the cone in order to retain the water inside yet provide a transparent acoustic window. We used several cone heights, to place the focus at different depths in the tissue. This was important in the larger liver lobes of the pigs, in order to cauterization completely through the lobe. Utilizing these methods, liver lobes were treated to transect distal regions. A cauterized strip was made across the tip portion of a liver lobe by scanning the HIFU transducer across
it, producing a cauterization as shown (Figure 1A). The tissue to be resectioned was removed by cutting along the distal border of the strip. No oozing from the liver parenchyma was observed, except in a few cases when the cross-sections were incompletely cauterized (Figure 1B). Additional applications of HIFU were then needed. The larger vessels (> 2 mm inside diameter) in many cases bled and we also applied further HIFU there. However, this did not always work (particularly in the case of the larger hepatic veins) and it required ligation to stop the bleeding. The larger the region, the more the difficulty there was in this regard. We successfully transected the distal tip of liver lobes in rabbits were the thickest transactional region was 1 cm with no bleeding or need for ligation. In the largest resection, a pig liver lobe (5 cm thick), ligatures were required for the larger vessels for complete hemostasis.

DISCUSSION AND CONCLUSIONS

Resectioning liver can be quite time consuming and can involve considerable blood loss. Much of this time involves stopping bleeding from the parenchyma. The larger vessels are quickly ligated once located. Concern also remains after the surgery, whether re-bleeding may occur in the insulted parenchyma. The use of HIFU to pre-cauterize before sectioning offers an attractive alternative to current methods, if it can be developed to be reliable, easy and fast to use. In our early work, we have demonstrated the potential of the use of HIFU in this way. The greatest difficulty in its use was in occluding flow from the larger vessels but these are fairly easy to treat with conventional approaches as mentioned. Technical improvements are needed to provide rapid changing of the focal depth to quickly obtain complete cross-sectional cauterization. Our technique of changing cones on the transducer was too cumbersome and time-consuming for clinical use. Development of a system for rapid scanning and focusing at various depths would facilitate the use of HIFU as tool for bloodless liver surgery. Finally, survival animal studies are also needed to learn about the possibilities of re-bleeding after abdominal closure.

REFERENCES