Narrative: Right Angle Harmonic Scalpel

Designer: Mark A. Carlson, MD

Abstract. The Right Angle Harmonic Scalpel is an instrument designed for minimally invasive (laparoscopic) surgery that combines the action of a right-angle dissector and a Harmonic Scalpel® (Ethicon Endo-Surgery) into one device. A prototype of the Right Angle Harmonic Scalpel has not been constructed.

Introduction. The ultrasonic shears (Figure 1) is a hemostatic cutting instrument that has been in use for minimally invasive surgery for about 10 years. The ultrasonic shears, also known as the Harmonic Scalpel®, is manufactured by Ethicon Endo-Surgery, a subsidiary of Johnson & Johnson. The Harmonic Scalpel consists of a laparoscopic shears (Figure 1A-B) connected to a power source (Figure 1C). The surgeon grasps tissue which needs to be transected in the jaws of the shears (Figure 1D). Power then is applied to instrument in the form of high frequency (“ultrasonic”) vibration to the rigid arm of the instrument. This vibratory energy is transmitted to the tissue within the jaws of the shears, and this energy denatures, dehydrates, and coagulates the proteins within the shears. Any blood vessel within the affected tissue almost instantaneously is sealed. After several seconds of power application, the jaws slice through the grasped tissue. So the harmonic scalpel first achieves blood vessel hemostasis, followed by tissue transection. The combination of these two actions in one instrument, the Harmonic Scalpel, has enabled the minimally invasive surgeon to be quicker and safer than what was feasible with older, more conventional instruments.

Rationale for a modification to the Harmonic Scalpel. In situations where the tissue to be transected is plainly visible (such as that shown in Figure 1D), the conventional Harmonic Scalpel works well. In situations where physical relationships of the tissue are not obvious, however, the use of the Harmonic Scalpel can be difficult and cumbersome. In one common scenario, for example, a surgeon may be presented with bands of tissue lying deep within a recess formed by two adjacent organs, as shown in Figure 2A-B. (A specific example of this would be the short gastric vessels which lie between the fundus of the stomach and the superior pole of the spleen.) The available angles of instrument approach limit the surgeon’s ability to grasp and cauterized tissue in such a deep recess. The surgeon can handle this difficulty by first isolating some tissue using a laparoscopic right-angle dissector (Figure 2C-F). A right-angle dissector has a 90˚ bend in its jaws, which facilitates the dissection and separation of tissues. This maneuvers shown in Figure 2 necessitate multiple instrument changes through the laparoscopic trocars, which can consume time over the course of a long procedure. In addition, although the right-angle dissector can isolate tissue for subsequent application of the Harmonic Scalpel (Figure G-H), the isolated bundle of tissue may retract back to its original position immediately after withdrawal of the right-angle dissector. The bundle then would no longer be visible for cauterization/transection by the Harmonic Scalpel.

The situation shown in Figure 2 demonstrates a shortcoming of the conventional Harmonic Scalpel: its poor adaptability for the performance of dissection in difficult-to-reach spaces during laparoscopic surgery. One solution employed for this problem involves the use of multiple instruments to perform the dissection, as shown in Figure 2; this approach is cumbersome and inefficient. Alternatively, the surgeon may try to “force the issue” with the Harmonic Scalpel alone, i.e., attempting to dissect out the tissue with the non-angled jaws of the conventional ultrasonic instrument. This latter approach is suboptimal at best, and dangerous at worst. A third, unexplored, solution to this problem (and the topic of this proposal) would be to combine the utility of the right-angle dissector with the efficacy of the Harmonic Scalpel into one instrument.

The instrument combination: the Right Angle Harmonic Scalpel. The surgical device of this proposal is the Right Angle Harmonic Scalpel (Figures 3-7; details of the instrument design are included in the Figure Legends). As alluded to above, the Right Angle Harmonic Scalpel combines the dissecting ability of the right-angle dissector with the cauterization/transection ability of the Harmonic Scalpel. Such an instrument should safely speed and simplify the performance of laparoscopic procedures which involve difficult dissection in deep recesses (such as Nissen fundoplication, splenectomy, adrenalectomy, colon resection, and gastric bypass). A conceptualized lateral view of the Right Angle Harmonic Scalpel is shown in Figure 3. The Right Angle
Harmonic Scalpel is similar in appearance to the Harmonic Scalpel currently in use (Figure 1), except with the addition of the right-angle mechanism and related controls. Of note, the proposed instrument has a shaft diameter of 10 mm. The Harmonic Scalpel from Ethicon comes in both 5 and 10 mm versions. There is a trend to employ narrow diameter (5 mm and below) instrument in laparoscopic surgery, because of the perception that there are fewer trocar-related complications with narrower instrumentation. The Right Angle Harmonic Scalpel has been conceived initially as a 10 mm instrument in order to facilitate the engineering of its internal mechanics. If the instrument is successful, then it is possible that the instrument diameter eventually could be reduced to 5 mm.

Another difference between the Harmonic Scalpel from Ethicon and the proposed Right Angle Harmonic Scalpel is the presence of roticulation control in the former (see Figure 1A&B, and Figure 3c), which allows 360° rotation of the instrument shaft. By turning a black knob on the instrument handle with the index finger (see inset Figure 1B), the surgeon can rotate the jaws of the Harmonic Scalpel to best suit the task at hand. This control has not been included with the initial design of the Right Angle Harmonic Scalpel in order to facilitate its engineering. It is conceivable that roticulation control could be added in at a later time. The lack of roticulation control would be only a minor detract from the proposed instrument. The length of the proposed instrument is a standard 45 cm; it should be feasible to offer the instrument in 60 cm or longer lengths for bariatric surgery.

Close up views of the jaws of the Right Angle Harmonic Scalpel are shown in Figure 4, and the action of the instrument jaws is shown in Figure 5. The right-angle portion of the Right Angle Harmonic Scalpel works similarly to a conventional right-angle dissector, except that one jaw (the lateral) of the former needs to fixed; the opposite (medial) jaw provides the scissor motion. This is necessary because efficient transmission of ultrasonic energy through the instrument shaft into the tip (i.e., the lateral jaw) requires a straight, rigid arm with precise harmonic qualities. The mechanism of the harmonic clamp is shown in Figure 6; the stowed (retracted) position of the arm also is shown in Figures 4 and 5. This harmonic clamp is a rotating arm which the surgeon deploys to compress the dissected tissue against the right-angle jaws. Such compression is necessary for optimal transmission of the harmonic energy into the tissue. As drawn, the harmonic clamp requires slightly more than a 180° rotation for full deployment. To accomplish this rotation, a thumbwheel mechanism is utilized in the instrument handle (Figure 7). The rotation of the thumbwheel is translated into rotation of the harmonic clamp through a mechanical linkage. An end-on view of the Right Angle Harmonic Scalpel is shown in Figure 8.

**The Right Angle Harmonic Scalpel in action.** As described above, the Right Angle Harmonic Scalpel performs both the action of a right-angle dissector and a conventional Harmonic Scalpel (Figure 9). The surgeon first gets around a difficult-to-reach segment of tissue/blood vessel with the right-angle jaws, and creates a window underneath this tissue. After the target is sufficiently dissected, the surgeon deploys the harmonic clamp, and then applies the ultrasonic energy. Compared to the technique described in Figure 2, there is a minimum of wasted motion and time, with equivalent or improved patient safety.
Figure Legends

1. *The Harmonic Scalpel® (aka ultrasonic shears), a product of Ethicon Endo-Surgery.* (A) Close-up view of the instrument handle and the shear-like tips. (B) Full lateral view. (C) The instrument power source, and additional close-up views of the instrument tips. (D) Intraoperative photograph of the ultrasonic shears in action. The shears are coming in from the right, and are grasping tissue with blood vessels located between the greater curve of the stomach and the spleen. The ultrasonic energy applied by the instrument will coagulate the vessels and transect the tissue. [All images in Figure 1 were downloaded from the internet.]

2. *Tissue transection in deep recesses using the Harmonic Scalpel.* (A) Hypothetical end-on view of some connective tissue stretched between two intra-abdominal organs (a and b). There are blood vessels within this connective tissue that the surgeon desires to transect and seal. The Harmonic Scalpel (c) is shown superiorly, approaching from an angle which is typical during a laparoscopic procedure. (B) Overhead view of the organs and tissue in A; this is what the surgeon typically sees through the laparoscope. The surgeon will have a difficult time grasping the connective tissue in the shears of the Harmonic Scalpel (c), because the tissue is protected in the recess formed by organs a and b. (C-D) One approach to this problem of surgical exposure is to use a laparoscopic right-angle dissector (d) which, as its name implies, has a 90˚ bend in its jaws. The right-angle dissector can be insinuated underneath and around a segment of tissue between organs a and b, which isolates this segment in preparation for the Harmonic Scalpel. (E) The spreading action of the jaws of the right-angle dissector opens up a “window” beneath the isolated segment of tissue, which will allow passage of the lower jaw of the Harmonic Scalpel. (F) The right-angle dissector then is withdrawn, leaving the isolated segment of connective tissue between organs a and b ready for cauterization/transection by the Harmonic Scalpel. (G) The Harmonic Scalpel (c) then is inserted, the tissue segment is grasped in the instrument’s jaws, and ultrasonic energy is applied. (H) After completion of the cauterization/transection, the Harmonic Scalpel is withdrawn, leaving two cauterized ends of tissue.

   Key:
   a  intra-abdominal organ
   b  intra-abdominal organ
   c  Harmonic Scalpel
   d  laparoscopic right-angle dissector

3. *The Right Angle Harmonic Scalpel, full lateral view.* The proposed instrument has a similar shape to the conventional Harmonic Scalpel shown in Figure 1.

   Key:
   a  instrument jaws
   b  shaft
   c  roticator control
   d  cutting and coagulation control
   e  finger grips
   f  thumb wheel for control of harmonic clamp
   g  body of handle
   h  location of power cable insertion.

4. *Right Angle Harmonic Scalpel, 90˚ views of instrument jaws.* A close-up of the instrument tip, showing the relationships of the jaws and the harmonic clamp in top and side views.

   Key:
   a  lateral jaw
   b  medial jaw
   c  harmonic clamp
5. **Right Angle Harmonic Scalpel, demonstration of right-angle mechanism.** Closed and open positions of the right angle jaws, viewed from the top. Extension of the finger grips (not shown) drives a spring-loaded connecting rod forward, which swings the medial jaw open via the medial jaw linkage. Subsequent closure of the jaws is performed by compression of the finger grips, and is aided by the spring loading.

Key:
- a lateral jaw
- b medial jaw
- c harmonic clamp
- d medial jaw linkage
- e horizontal lever arm
- f vertical lever arm

6. **Right Angle Harmonic Scalpel, demonstration of harmonic clamp mechanism.** (A) Stowed (retracted) position. The harmonic clamp is recessed in its slot, so the instrument can be inserted and maneuvered without restriction from the clamp. (B-C) Phases of harmonic clamp rotation. The thumbwheel (not shown) is turned by the surgeon; a mechanical linkage translates this movement into clamp rotation. (D) After full deployment, the harmonic clamp comes to rest on top of the lateral right-angle jaw (through which the harmonic energy is transmitted). To retract the clamp back to the stowed position, the surgeon reverses the rotation on the thumbwheel.

Key:
- a lateral jaw
- b medial jaw
- c harmonic clamp
- d medial jaw linkage
- e horizontal lever arm
- f vertical lever arm

7. **Details of the harmonic clamp mechanism with thumbwheel.** (A-E) The harmonic clamp is shown progressing from the stowed position to the clamped position; each progressive panel of this Figure shows the thumbwheel and harmonic clamp going through 45° of rotation. A series of connecting rods links the rotation of the thumbwheel with rotation of the harmonic clamp; this action facilitated by two lever arms (offset by 90°) on the harmonic clamp. [Figure not to scale.]

Key:
- a horizontal lever arm (red)
- b vertical lever arm (blue)
- c harmonic clamp
- d vertical lever linkage (red)
- e horizontal lever linkage (blue)
- f thumbwheel

8. **Right Angle Harmonic Scalpel, end-on view.** The instrument is viewed end-on with the jaws facing the viewer. The bulk of the handle and grips (which should be visible in the background) are not shown. The surface of the right-angle jaws are serrated.

Key:
- a lateral jaw
9. Tissue transection in deep recesses using the Right Angle Harmonic Scalpel. This Figure illustrates the same intraoperative situation presented in Figure 2, but this time using the new instrument. (A) The Right Angle Harmonic Scalpel (c) is inserted into the abdomen in order to seal and transect a blood vessel (d) lying within connective tissue that is recessed between 2 intra-abdominal organs (a & b). (B-C) The jaws of the Right Angle Harmonic Scalpel are slid under and around the target vessel, creating a “window” beneath the vessel. (D) The surgeon spreads the jaws of the Right Angle Harmonic Scalpel, which enlarges the window beneath the vessel in preparation for sealing and transection. (E) With the instrument still in place, the surgeon closes the harmonic clamp over the target vessel with the thumbwheel (not shown) on the handle of the Right Angle Harmonic Scalpel. (F) The surgeon applies harmonic energy to the instrument, which seals and transects the target vessel in the same fashion as the conventional Harmonic Scalpel.

Key:
- a intra-abdominal organ
- b medial jaw
- c harmonic clamp
- d slot for harmonic clamp lever arms
- c Right Angle Harmonic Scalpel
- d target blood vessel
Figure 1
Figure 3

Right-angle harmonic, full lateral view
Right-angle harmonic, 90° views

Figure 4
ADDENDUM

Side view of proposed harmonic right angle

(A) Straight rigid arm for transmission of ultrasonic energy
(B) Hardened plastic sheath
(C) Tip of right angle
Figure 5

Right-angle action
Harmonic clamp action

Figure G
Figure 7

Harmonic clamp with thumbwheel
Right-angle harmonic, end view a

Figure 8

b 10 mm