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Current State of Scanning Micromanipulator Applications With the Carbon Dioxide Laser

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Objectives: The development of the scanning system AcuBlade has considerably enhanced carbon dioxide laser energy delivery, improving cutting and ablation modes. The scanning system can be applied with the 2 available high-powered pulsed waves, SuperPulse and UltraPulse. This study was conducted to determine whether there are any differences in phonosurgery between the SuperPulse and UltraPulse lasing applications with regard to thermal diffusion into the surrounding tissues, healing time, and clinical results.

Methods: Thirteen patients with bilateral and similar vocal fold lesions underwent operation — one side in SuperPulse mode and the other side in UltraPulse mode. The parameters for phonosurgery were depth of 0.2 mm, 10 W, single pulse, and 0.10 second for SuperPulse, and 2 passes, 10 W, single pulse, and 0.10 second for UltraPulse.

Results: Incisions were sharper with UltraPulse, making the surgery easier, but at the first postoperative follow-up visit, after 8 to 10 days, no differences were observed in the presentation, the healing, or the vibration of the 2 vocal folds. Coagulation along the incision line was 25 μm for SuperPulse and 15 μm for UltraPulse (median values).

Conclusions: In comparison with SuperPulse, the UltraPulse carbon dioxide laser made the procedure easier, but did not improve the clinical outcome.

Key Words: carbon dioxide laser–assisted phonosurgery, robotic scanning application, vocal fold.

INTRODUCTION

From its inception, the carbon dioxide (CO_2) laser was intended for surgery.[1] It emits electromagnetic energy at a wavelength of 10.6 μm. This wavelength has a high coefficient of absorption for water. Soft tissues with a high water content therefore strongly absorb CO_2 laser energy.[2] The CO_2 laser induces little collateral thermal tissue interaction with a penetration ranging in micrometers.[2]

These features make the CO_2 laser the surgical workhorse when tissue incision or vaporization with minimum concomitant collateral damage is required.[3]

In terms of laser light delivery from the laser arm to the target, we currently have available the AcuSpot micromanipulator and the scanner.

The micromanipulator, which is attached to the operating microscope, yields the smallest possible beam diameter presently available, ie, 250 μm for a local length of 400 mm. This micromanipulator makes possible the accurate tissue incision and dissection required for phonosurgery.[4,5]

The scanner is a device connected between the laser arm and the micromanipulator. The micromanipulator and the scanner form together the so-called scanning micromanipulator.

By means of a computer-guided system of rotating mirrors, the scanner[6] allows the beam to sweep a given surface with extreme rapidity. This feature makes it a very effective tool when macroscopic vaporization is required. A "shaving" effect a few micrometers deep is achieved during each beam sweep with very little in-depth thermal penetration. The usual shape chosen for the surface is the circle.

The AcuBlade is a scanner software modification that allows the beam to travel across the target as a straight or curved incision line instead of "shaving" a given surface (Fig 1). Various lengths (range, 0.5 to 3.5 mm) and penetration depths (range, 0.2 to 2 mm) are programmable. The operator can, at all times, modify the parameters proposed by the laser-controlling software. The software-calculated penetration depth is based on the average absorption of

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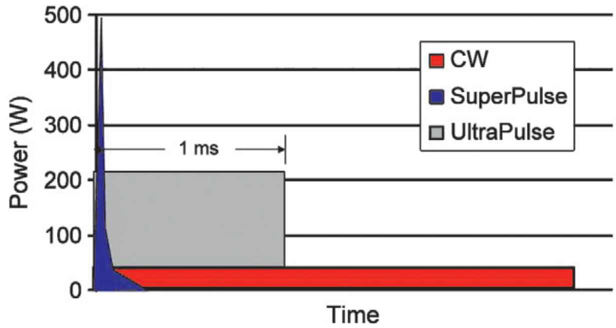

Fig 1. AcuBlade operating modes. AcuBlade is scanner software that allows beam to sweep given surface with extreme rapidity or to travel as straight or curved incision.

the CO_2 laser by living soft tissues. Depending on the desired length and penetration, the software calculates the required power and pulse duration for the single pulse mode. This incision line can be rotated to the left or right with the joystick.

The thermal reduction is even more important with SuperPulse or UltraPulse waves. SuperPulse and UltraPulse are pulsed waves with a high peak of power delivered in millisecond pulses or less. The resultant average pulse power, predetermined during programming, usually ranges between 1 and 10 W. The interpulse pause of approximately 1 ms, called the thermal relaxing time, permits the tissue to cool. This significantly reduces the thermal effect and consequent coagulation of the area surrounding the impact. SuperPulse has higher peak power (400 to 500 W) than UltraPulse (200 W) but less energy, be-

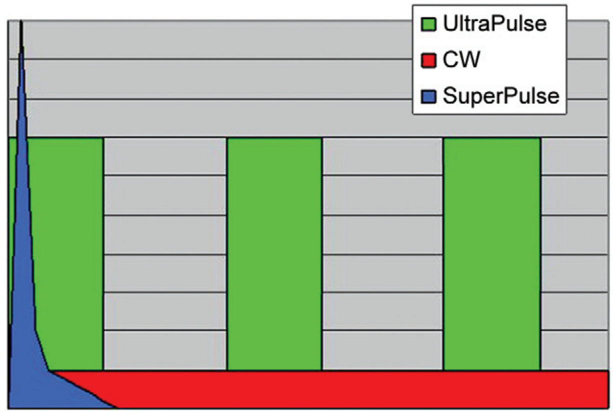

Fig 2. Laser output SuperPulse has higher peak power than UltraPulse, but clearly less energy (because blue area is smaller than green one). Amount of pulse energy determines tissue impact, provided both pulses are within thermal relaxation time of approximately 1 ms. CW — continuous wave.

cause its delivery time is shorter (Fig 2). This pulse energy determines tissue impact and must reach the necessary threshold for ablation. Energy below ablation threshold leads to stronger thermal impact. UltraPulse adjusts its pulse energy automatically such that it is always above ablation threshold. This is not the case with SuperPulse (Fig 3). SuperPulse is cone-shaped, and this sort of energy goes into tissue and heats it up more. UltraPulse is very rectangular. Thus, there may be slightly more thermal damage with SuperPulse than with UltraPulse.

The AcuBlade was designed for SuperPulse and continuous modes that can originate from the same

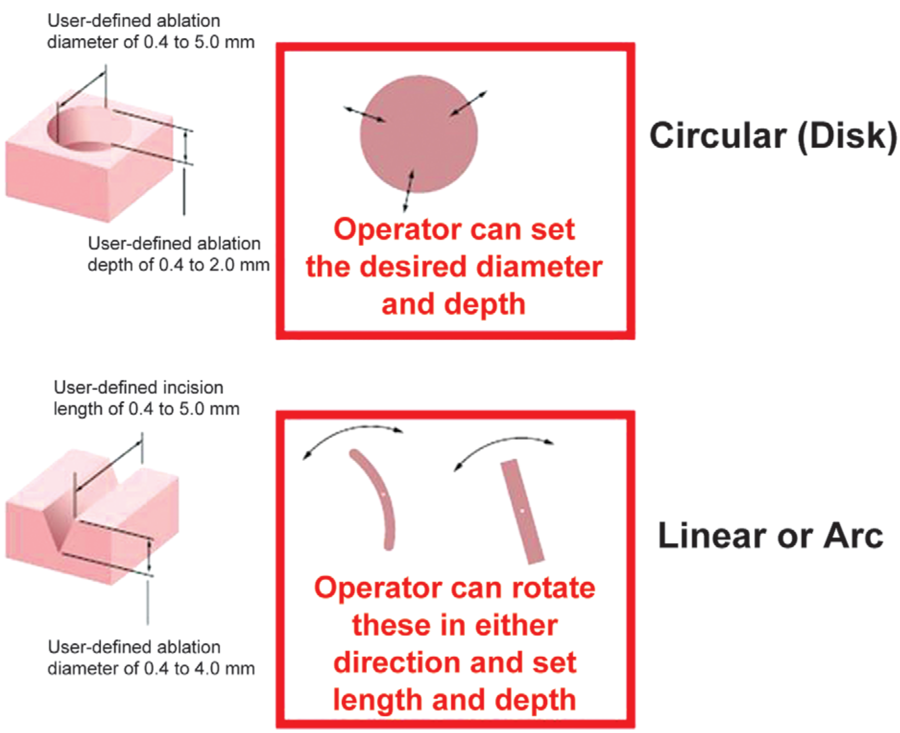

Fig 3. UltraPulse adjusts its pulse energy automatically such that it is always above ablation threshold. This is not true for SuperPulse.

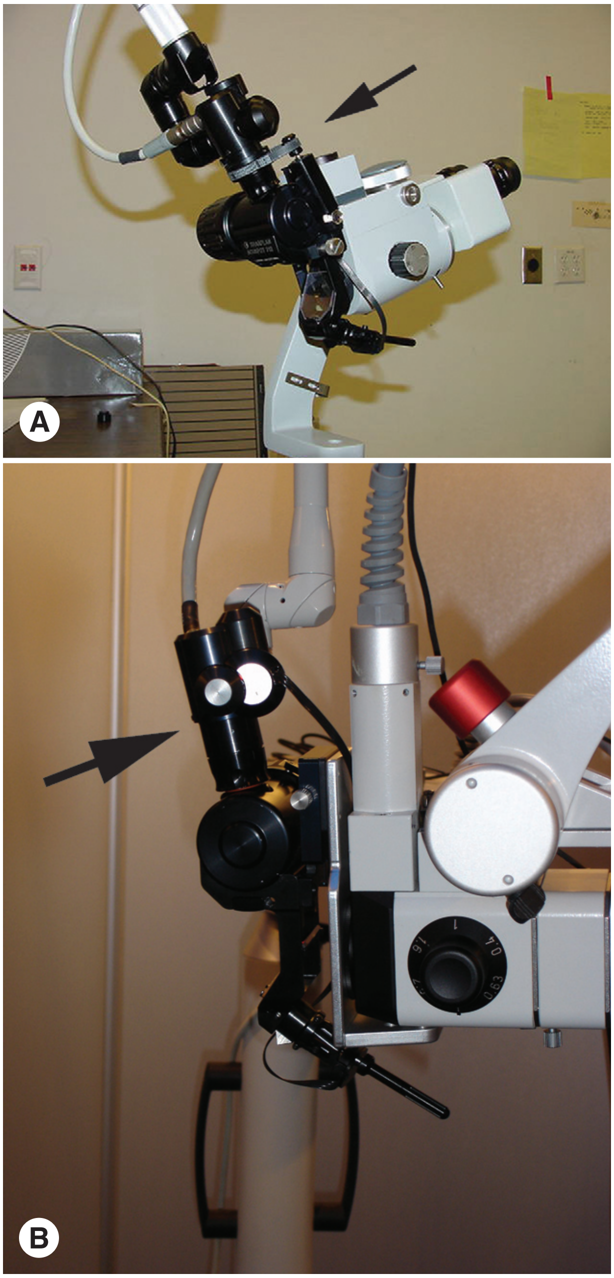

Fig 4. Scanning system. **A)** This incision line can be rotated to left or right thanks to driving belt articulated with scanner. This belt is moved with joystick-controlled electrical motor (arrow). **B)** With UltraPulse technology, guiding system of incision line is fully electronic and integrated in scanner (arrow).

optical cavity.[6] With this system, the incision line is rotated to the left or right with the joystick, thanks to a driving belt articulated with the scanner. This belt is moved with a joystick-controlled electrical motor (Fig 4A).

The AcuBlade is now available with the UltraPulse technology. The guiding system of the incision line is fully electronic and is integrated in the scanner (Fig 4B).

We conducted a prospective study to ascertain whether there were any clinical differences in phonosurgery between SuperPulse and UltraPulse lasing applications (both compatible with the scanning system) with regard to thermal diffusion, healing, and clinical results.

MATERIALS AND METHODS

Thirteen patients with bilateral and similar vocal fold lesions underwent operation with the AcuBlade — one side in SuperPulse mode (Compact laser 1040C, Lumenis, Santa Clara, California) and the other side in UltraPulse mode (Encore, Lumenis). There were 5 cases of type III Reinke's edema according to Yonekawa,[7] 4 nodules, 3 leukoplakias, and 1 type III sulcus[8] (referred to as opened cysts by Bouchayer et al[9]). As the lesions were bilateral and similar, it was decided to use the SuperPulse mode for the right vocal fold and the UltraPulse mode for the left vocal fold.

The parameters for phonosurgery were depth of 0.2 mm, 10 W, single pulse, 0.10 second for SuperPulse; and 2 passes, 10 W, single pulse, 0.10 second for UltraPulse. The length of the incision line was 1 to 2 mm, according to the lesion to excise. The parameters chosen for SuperPulse have been proved effective. The parameters for UltraPulse are similar; 2 passes means that the laser beam travels twice across the incision line to obtain a 0.2-mm depth of incision.

Subglottic high-frequency jet ventilation is usually performed with a metal catheter (Mayné-Remacle catheter),[10] which can be connected to most laryngoscopes. Nodule, leukoplakia, and sulcus cases underwent excision. Before excision of nodules and sulci, the lesion was grasped with a Bouchayer microforceps (MicroFrance, Medtronic Xomed, St Aubin Le Monial, France) and stretched toward midline to define the plane between it and the vocal ligament. A subepithelial cordectomy (type I) according to the European Laryngological Society[11] was performed for the leukoplakia cases. Its main role was diagnostic, to allow histologic examination of the entire epithelium of the vocal fold.

For Reinke's edema, the procedure was derived from that of Hirano.[12] The operation commenced by coagulating the microvessels on the upper surface of the vocal fold. The laser was set at a 0.05-second pulsed exposure of 1 W with a slightly defocused beam. The epithelium was then incised along the length of the upper surface, from the vocal process up to 2 to 3 mm from the anterior commissure. After the incision, the freed flap was pulled away toward the midline with Bouchayer forceps, and the glue

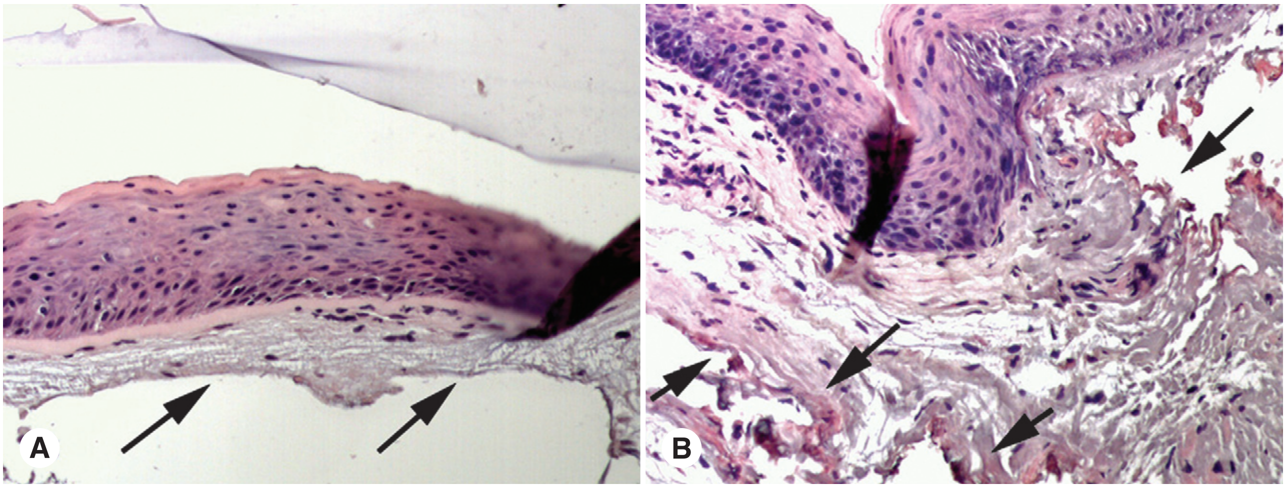

Fig 5. Coagulation along incision line (arrows) with **A)** UltraPulse and **B)** SuperPulse (H & E; original ×20).

that had accumulated within Reinke's space was aspirated. Then any excess epithelium was excised in order to achieve a better edge-to-edge fit of the incision.

Although the use of fibrin glue is somewhat empirical, we subscribe to the view of Bouchayer and Cornut[13] that it is useful for covering the site of the operation. It possibly acts as scaffolding for regeneration of epithelium, and discourages any potential for granuloma formation.

After phonosurgery, a strict 8-day vocal rest is prescribed. The medical treatment consists of steroid aerosols, oral antibiotics, and proton pump inhibitors for 8 to 10 days, at the end of which the assessment takes place. Besides the objective voice assessment, the vocal fold healing and vibration were checked by stroboscopy.

Using a ruler adapted to the pathologist's microscope, one of the authors (M.-C.N.) measured on the operative specimens the laser-produced coagulation thickness at the incision. The specimen was oriented according to the slice to observe the different parietal planes from the epithelium to the margin and was embedded in agar (gelatin) in this position.

Twisting of the specimens was frequently observed because of their small size, the coagulation at the margin, and the embedding process. The pathologist checked the specimens for an area in which there was no twisting or tangency effect increasing the thickness. These areas are usually very rare on such small specimens; hence, only one measurement per specimen was made.

Thermal damage was defined as a layer of cells exhibiting thermal cellular necrosis, ie, loss of nucleus, denatured cytoplasmic protein, and membrane disruption (Fig 5).

RESULTS

Incisions are sharper with UltraPulse, making the surgery easier. This is obvious through the microscope, mainly for tissues that contain less water, such as keratotic epithelium or sulcus.

Irregular incisions and possible charring as observed with the basic microspot were already well improved with the AcuBlade and SuperPulse,[6] but the irregularities still observed in thicker tissues were not present anymore with UltraPulse, so the dissection was more comfortable for the surgeon, especially when we approached major vocal fold structures such as the vocal ligament.

The postoperative period was overall uneventful. We did not observe any AcuBlade-induced intraoperative or postoperative complications. The first postoperative follow-up examination, conducted at 8 to 10 days, revealed, on stroboscopic examination, complete healing and normal vocal fold vibration following phonomicrosurgery for simple lesions such as nodules or type III sulcus.

Surgery addressing Reinke's edema required 2 to 3 weeks before normal and symmetric vibration was present, but this was not dependent on one or the other CO_2 laser wavelength. This observation was the same for the leukoplakia cases.

The mean coagulation along the incision line was 29 ± 14 μm for SuperPulse and 20 ± 11 μm for UltraPulse. The median values were 25 μm for SuperPulse and 15 μm for UltraPulse ($p < .001$). The cases are presented in detail in the Table.

DISCUSSION

In phonomicrosurgery, the AcuSpot micromanipulator has rendered incision with limited thermal

BREAKDOWN OF CASES

				SuperPulse		*UltraPulse*	
Patient	*Sex*	*Age (y)*	*Lesion*	*Vocal Fold*	*Thermal Damage (μm)*	*Vocal Fold*	*Thermal Damage (μm)*
5	F	48	Keratosis	L	20	R	15
9	M	69	Keratosis	L	25	R	15
13	M	72	Keratosis	L	20	R	15
4	F	31	Nodules	L	20	R	10
10	F	30	Nodules	R	25	L	15
11	F	35	Nodules	R	70	L	50
12	F	15	Nodules	L	40	R	20
7	F	34	Open cyst	R	30	L	35
1	M	52	Reinke's edema	L	12.5	R	15
2	F	51	Reinke's edema	R	32.5	L	20
3	F	63	Reinke's edema	R	25	L	15
6	F	49	Reinke's edema	L	30	R	20
8	M	58	Reinke's edema	L	25	R	15

damage possible.[4,14] Single-pulse dissection, however, required for accurate procedures, does not attain an incision as regular as that achieved with microscissors; the edges of the incision appear slightly indented. This is the result of the dot-per-dot incision with the microspot and the circular distribution of the laser beam energy around this spot.

While achieving hemostasis unattainable with cold instruments, the AcuBlade also provides a regular incision. Because the sweeping speed is constant, the energy distribution is uniform along the entire length of the line. This ensures a more even incision and an improved hemostasis in comparison with the results achieved with the manually guided beam.

When combined with the AcuBlade, UltraPulse provides sharper incisions than SuperPulse, making the procedure easier, especially for thicker epithelium with less water content. This cannot be objectively measured, but is obvious during the procedure. This difference in ease is interesting for delicate phonosurgeries of the vocal fold in single-pulse mode, but this is not an advantage for other procedures, such as cordectomy, in which the shooting is usually in continuous mode. On the contrary, more coagulation along the incision line can be expected.

In order to ensure uniform incision, caution must be taken to constantly maintain in the same dissection plane the tissue that requires incising. Nonobservance of this principle results in a defocused line over a more or less large portion of its length with consequent reduced incision uniformity.

The fully electronic UltraPulse scanning system is more practical. There is no need to move the scanner with the driving belt to rotate the incision line, which carries the risk of hitting the laryngoscope if the axes of the microscope and laryngoscope are not aligned.

For the surgeon with little CO_2 laser experience in vocal fold microsurgery, the "dot-per-dot" method with the basic microscope[14] remains, however, preferable, in order to avoid a misoriented beam, which is fraught with more consequence when delivered along a line than when delivered on a single point.

The differences between SuperPulse and UltraPulse in their use for the AcuBlade are only perceptible during surgery. They do not affect the postoperative period; after 8 days, the quality of the healing and the vocal fold vibration are similar. From there, the obtained functional voice outcomes were as expected and did not add any information.

Microscopic examination of the incision edges reveals that the AcuBlade causes less charring than a manually guided beam.[6] The decrease in thermal effect is achieved by the accuracy and speed of the laser beam sweep along the software-programmed line. Manual control cannot achieve such thermal reduction.

Differences in results are observed between SuperPulse and UltraPulse when combined with the AcuBlade. The coagulation lines are smaller: 15 μm instead of 25 μm with SuperPulse for the median values. This could be expected from the physical parameters of the 2 pulsed waves. UltraPulse produces more pulse energy than SuperPulse, and always above the ablation threshold. Its peak is rectangular. The SuperPulse peak is conical, with a part of its energy under the ablation threshold, which induces more thermal effects in the surrounding tissues. The median values of coagulation thickness, 15 μm with UltraPulse and 25 μm with SuperPulse, are higher than those observed in a previous study[6] with less than 10 μm for phonomicrosurgical procedures. But this present series includes cases of leukoplakia and open cysts, and the previous series included mainly exudative lesions of Reinke's space,[15] such as nodules, polyps, and Reinke's edema.

CONCLUSIONS

The AcuBlade combined with the UltraPulse technology is a very effective tool for CO_2 laser–assisted microsurgery. The sharper incision of UltraPulse makes the procedure easier. That fact does not affect the postoperative period or the functional results. The coagulation width along the incision line is 15 μm with UltraPulse and 25 μm with SuperPulse (median values) with use of the usual parameters for vocal fold microsurgery.

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