Acquainting Professor Chung-li Wang was the turning point of my career as a researcher. Before getting to know him, I was an aerospace engineer playing with airplanes, helicopter, and space-shuttle design. Luckily, through the introduction of Professor Fon-jou Hsieh, I became a member of biomedical research for the past 16 years. I joined the musculoskeletal ultrasound study group first, where we met and studied the basic principles of ultrasound every week for more than 3 months. With Professor Hsieh’s assistance, we were allowed to use the ultrasound equipment in the hallway of National Taiwan University Hospital on Saturday afternoons and Sundays. This was the beginning of our adventure in the arena of ultrasound. Even to this day, it is still one of my most cherished memories, and I am filled with gratitude whenever I think back to those times.

Using ATL Ultramark, I got my first set of ultrasound images (Fig. 1). It was the M-mode and Doppler spectrum of Dr Chih-Chin Hsu’s common carotid artery (CCA). When I saw the M-mode image, I was very excited to see how similar the pulse of the arterial wall and the blood pressure were, and how convenient it was to measure the blood flow of the CCA. An innovative and easy way to measure the resistance of cerebral circulation immediately came to my mind. I returned to my lab and quickly wrote a MATLAB image analysis program to investigate impairment of the carotid artery, which can be applied to analyze the condition of the artery in patients with stroke. It can also be used to verify the characteristic frequency of systemic circulation and organs, and indirectly observe the hidden rules of dynamic allocation of vascular circulation. Not long after that, we gained access to the ATL HDI-3000 ultrasound system, which was incredible for the team. Professor Wang paid special attention to the ultrasound examination of ankle bone tendons and, in addition, we were also interested in studying the hemodynamics of the arteries by investigating the monophasic/triphasic pattern of the Doppler spectrum during recovery from bone fractures. Dr Chih-Chin Hsu’s and Dr Jeng-Yi Hsieh’s were proficient in analyzing the mechanical properties of plantar soft tissue and carpal tunnel syndrome, respectively, using musculoskeletal ultrasound. Apart from the study of tendon–ligament imaging for rehabilitation, Dr Tyng-guey Wang applied the circulatory resistance parameters—Doppler pulsatility index (PI) and resistive index (RI)—to the physical therapy of stroke patients. Our most important study that is worth mentioning was analyzing whether the PI and RI values of the inner carotid artery can be used to measure the flow resistance as results of brain activity. The aim of our study was to know whether it was possible to quantify a person’s potential to become the visiting staff/attending physician of a hospital based on their cerebral impedance. All the doctors who participated in our study had low CCA-RI values, whereas the engineering PhD candidates, who also participated in the study, had higher RI values compared with the physicians.

After familiarizing myself with the principles of ultrasound and the device manuals, I realized that the clinical ultrasound equipment has not been used to its maximum potential. However, I was very impressed with the ability of the ultrasound clinician to make up for any shortcoming of the equipment. For example, engineers usually like to focus on three-dimensional (3D) ultrasound imaging. Many
experienced doctors have stated that 3D ultrasound imaging is for beginners. Clinicians with extensive experience are able to convert the two-dimensional image they see into 3D in their mind. Without including the differentiable highlight in the image, 3D ultrasound alone has relatively little clinical value. In the same way, power Doppler and color Doppler images (CDIs) are both shown in color, but the imaging principles greatly vary. There is still a lot of room for improvement and expansion in terms of effectively applying the imaging in clinical settings.

As an instructor of basic ultrasound principles at the annual SUMROC, I was honored to be able to meet countless physicians and biomedical engineering experts. I would like to express my gratitude to them for their tireless efforts to share their clinical knowledge with me. I would like to thank Pai-chi Li, Tainsong Chen, Huihua Kenny Chiang, Ruey-feng Chang, Win-li Lin, Chung-ming Chen, and Jian-hua Zheng for their guidance in imaging engineering. I have been teaching physiological fluid dynamics for many years, and I know how important the clinical complications of vascular sclerosis are. I was fortunate enough to be able to consult with Professor Shoei-shen Wang and Professor Juey-jen Hwang individually on cardiovascular systems. I even had an eye-opening session, which I learned directly in an operating room. I also worked with Shu-Hsun Chu, Jeou-jong Shyu, and Nai-kuan Chou on the development of an artificial heart. Through animal testing, I began my journey in cardiovascular ultrasound. Many people understand the importance of studying arteriosclerosis. However, does anybody know the exact stiffness of the blood vessel in vivo? What is the relationship between arterial stiffness and its distance to the heart? To deliver blood to nearby organs and tissues, we must take the width, viscoelasticity, and resistance of the blood vessel into account. There has been little literature on this topic, and little evidence based on the carotid arteries. Using the currently available technique (HDI-3000), it should be a relatively easy topic worth investigating. Therefore, the team introduced a method to measure the in vivo peripheral arterial stiffness and viscoelasticity using ultrasound. Our research on soft tissue viscoelasticity was quickly accepted and approved by international academic journals. In our team, Dr Chih-Chin Hsu, Mei-chuan Huang, and Professor Chung-Li Wang were the core members who gave endless support throughout the study.

In terms of power Doppler applications in obstetrics and gynecology, Professor Hsieh introduced me to several senior physicians from the Taiwan Society of Perinatology. Dr Ming-kwang Shyu and Dr Yi-Ning Su helped me in improving my clinical knowledge in this field. I was able to see how the 3D power Doppler images and arterial blood flow resistance can be used to quantify the risk of high-risk pregnancy and infant development disorders. In recent years, the number of new gynecologists has dropped in Taiwan due to the low birthrate, clinical risks, and the policies of the National Health Insurance program. I sincerely believe that this situation will improve soon with the advancement of equipment and the development of clinical applications of these imaging techniques. I stepped into urology when I met Dr Shih-chiejg Chueh and Dr Shomon Wang. They applied these same power Doppler resistance analysis techniques to kidney transplants. As a result, doctors can see signs of acute kidney rejection and kidney failure at an earlier stage. It is certainly good news for the growing number of patients in Asia who require dialysis.

In late June, 2000, Dr Tzu-yu Hsiao joined the team, and became the leader of vocal cord ultrasound imaging. When we saw the CDI of the vocal cords (Fig. 2) we were all very excited. However, we did not know the exact CDI artifacts that resulted from high-pitched vibration. Professor Fon-jou Hsiao encouraged the team to investigate further because he believed that there must be a reason for these artifacts. The literature mistakenly stated that the CDI artifacts were a result of the air flow through the throat. Professor Hsiao gave me his book on the vocal cords. For the next 3 months, I studied otolaryngology and understood the ultrasound imaging principles of the vocal cords, and subsequently gained a deeper understanding of dysphonia in men and women, and the CDI artifacts caused by vocal cord polyps. As a result, a new chapter was added to the clinical textbooks on ultrasound image artifacts. In otolaryngology, ultrasound is often used to investigate tumors of the head and neck. However, in the future it may also be used as a clinical tool to examine vocal cords due to its convenience. In 2002, Professor King-jen Chang and Professor Fon-jou Hsieh established the angiogenesis research center, and the team began to focus on using ultrasound imaging to investigate the mechanical properties of diabetic arteries and the biophysics of tumors. Dr Chiung-nien Chen applied Professor Hsieh’s color Doppler vascularity index (VI) to
gastric cancer and colorectal tumors. He also became an internationally renowned researcher in cancer research using microarray gene-chip, which he co-worked with Professor Min-liang Kuo and his team. Using power Doppler, we developed a power Doppler vascularity index (PDVI), which can provide better resolution for vascular perfusion. Using the PDVI, one can easily determine the ratio of artery groups to vein groups in a tumor. A better interpretation can also be obtained on the heterogeneity of tumor tissues.

Since May 2005, I was given the responsibility of helping Industrial Technology Research Institute (ITRI) plan its medical device development. Despite the fact that I have transitioned from the academic community to the industrial sector, I have never forgotten to promote domestic ultrasound device development. Unfortunately, because the previous investment by the ITRI or Chung-Shan Institute of Science and Technology on ultrasound had not seen any meaningful revenue, the development of ultrasound devices has been stalled for more than 6 years. In 2010, Taiwan’s cross-strait business relationship with China experienced a significant improvement. High-level imaging devices (such as X-ray and ultrasound) were listed as among the key-demand devices for the new health-care system in China. In 2011, the domestic ultrasound research team was established, with duties assigned to the MOEA academic technology development program (TDP) (Taiwan National University), institutional TDP, and industrial TDP (Qisda, Chang Gung Medical Technology and Broadsound Corporation). All had the common goal of compensating for each other’s technology shortcomings. It is hoped that, in less than 3 years, high-quality and low-cost portable ultrasound machines can be mass produced for emerging markets such as China, Brazil, and Southeast Asia. At present, the desktop color Doppler ultrasonic product has been approved by the Taiwan Food and Drug Administration and the U.S. Food and Drug Administration. Although current research efforts are concentrated on the ultrasound hardware, clinician-directed specification will further increase its added value. Ultrasound for specialized usage, such as iPhones/iPads ultrasound, ultrasound for minimally invasive surgery, and pocket-sized ultrasound device for biopsy, as well as other applications, will be developed together with clinicians. It is foreseeable that these new developments will bring new energy to Taiwan’s biomedical ultrasound industry.

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