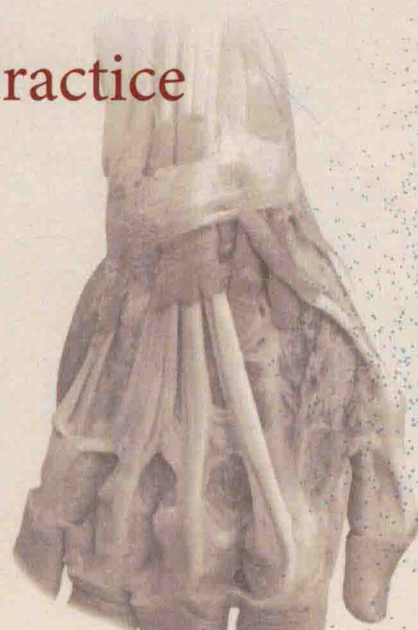
风湿病的肌肉骨骼超声——基础与实践

Musculoskeletal Ultrasonography in Rheumatology: Fundamental and Practice

主编　张卓莉



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主　编　张卓莉

副主编　邓雪蓉　耿　研

编　委　（以姓氏汉语拼音为序）

邓雪蓉（北京大学第一医院）
耿　研（北京大学第一医院）
郝燕捷（北京大学第一医院）
季兰岚（北京大学第一医院）
李　挺（上海交通大学医学院附属仁济医院南院）
李光韬（北京大学第一医院）
李家荣（香港养和医院）
宋志博（北京大学第一医院）
王　昱（北京大学第一医院）
张晓慧（北京大学第一医院）
张卓莉（北京大学第一医院）
赵　娟（北京大学第一医院）
周　炜（北京大学第一医院）

科学出版社

北　京

内 容 简 介

随着风湿超声影像在全球风湿病领域的发展，该技术已经成为多种风湿免疫病诊断标准中所涵盖的重要检查手段，也成为越来越多风湿科以及超声科医师临床中必备的工具。本书主要由北京大学第一医院风湿免疫科在肌肉骨骼超声方面有丰富经验的专家教授，在第一版《风湿性疾病的肌肉骨骼超声——标准化操作及应用》的基础上补充修订而成。在介绍超声基础知识、标准扫描规范的基础上，加入具体风湿性疾病不同病种中肌肉骨骼超声应用的国内外新进展文献综述以及常见的病变举例。本书一大特色是全书应用中英文双语书写，为学员提高专科英文阅读能力以及国际交流能力提供难得的学习平台。另一大亮点是文字图书配有丰富的彩色图片及教学视频，在理论教学的基础上，为实践教学提供生动、直观、实用、易学的工具。

本书为有愿望学习肌肉骨骼超声在风湿病中应用的多学科专业医师所设计，可以作为继续教育的参考用书，为广大学员提供标准化、国际化、图文并茂的学习教材。

图书在版编目（CIP）数据

风湿病的肌肉骨骼超声：基础与实践：双语版 = Musculoskeletal Ultrasonography in Rheumatology：Fundamental and Practice：汉英对照 / 张卓莉主编 . —北京：科学出版社，2018.11

ISBN 978-7-03-059384-9

Ⅰ . ①风… Ⅱ . ①张… Ⅲ . ①风湿病－肌肉骨骼系统－超声波诊断－汉、英 Ⅳ . ① R593.210.4

中国版本图书馆 CIP 数据核字 (2018) 第 252174 号

责任编辑：王锞韫　胡治国 / 责任校对：严　娜

责任印制：赵　博 / 封面设计：陈　敬

科学出版社 出版

北京东黄城根北街 16 号

邮政编码：100717

http://www.sciencep.com

三河市春园印刷有限公司印刷

科学出版社发行　各地新华书店经销

*

2018 年 11 月第　一　版　开本：787×1092　1/16

2018 年 11 月第一次印刷　印张：17

字数：440 000

定价：198.00 元

（如有印装质量问题，我社负责调换）

前言

——光明照亮黑暗

还清晰地记得30年前我刚刚接触风湿免疫学科时，我国的风湿病学也是处于起步阶段，现如今已经非常成熟且临床广泛使用的自身抗体检测在当时还在摸索中，随后20年经过不断的努力建立了各种自身抗体检测的可靠方法，建立了标准化检测流程，在全国普及推广，成为20世纪我国风湿病学得以快速发展的前提。进入21世纪，新型影像学技术逐步在各种风湿性疾病的诊断和治疗中尝试并得以应用。2003年我在英国工作期间第一次学习了肌肉骨骼超声技术，2007年在荷兰阿姆斯特丹医学中心工作时再次系统学习并在日常工作中应用了影像学技术，这些萌发了我要在国内风湿病学界普及和推广风湿影像学技术的念头。

必须承认2008年回国工作之后筹划普及和推广风湿病学影像技术在当年是一件非常具有挑战性的事情，几乎没有现成的资料可以参考、没有超声设备，除我以外没有掌握这方面知识的老师。庆幸的是，我和同事都无畏艰难，我们借设备，我们率先在自己科室开始应用，我们不断练习、不断总结、对年轻医师进行培训；更为庆幸的是，我们认识了香港的几位医生，并得到了他们巨大无私的支持和帮助。经过两年左右的准备，2010年我们举办了我国第一个风湿影像学培训班。培训班非常成功并得到了同行的高度认可和赞扬。之后我们每年坚持这项培训工作，到今天已经完成了30余期。

历经几年时间的积累，我们把标准化操作规范和自己的经验整理成册，于2013年9月出版了国内第一本有关风湿病肌肉骨骼超声的书籍——《风湿性疾病的肌肉骨骼超声——标准化操作及应用》，这本教科书给国内同行的实践操作提供了很大帮助，受到同行的欢迎，先后几经再版，已经售罄。

这几年我们完成了近十万人次的肌肉骨骼超声检查，陆续开展了一些科研工作，先后培训了千余名医生，在国内成立了影像学学组，我们科的两位年轻医生已经成为国际培训师。随着肌肉骨骼超声技术在我国的发展和国内外肌肉骨骼超声应用的最新进展，应着广大医生对参考书籍的迫切需求，我们觉得有必要再推出一本风湿病肌肉骨骼超声方面的晋级版书籍。

这本《风湿病的肌肉骨骼超声——基础与实践》是我们多年临床实践经验的总结，本书增添了很多国内外肌肉骨骼超声在风湿病中应用的最新进展，因此更具临床指导价值。另外，考虑到超声在整个亚太地区风湿病学中发展的现状，考虑到未来更多的国际交流与合作，我们决定采用中英文双语版形式。

从我们开始踏入风湿病影像学领域到今天已经走过10年历程，这期间多种影像学技术已经逐渐被纳入多种风湿免疫病的分类标准中。与30年来自身抗体检测的发展类似，我们相信经过不断的努力，影像学技术一定能给风湿免疫性疾病的诊疗插上翅膀，把风湿病的诊治带到一个新的高度，仿佛光明照亮黑暗，给更多的患者带来福祉。祝愿我国风湿免疫学的发展

越来越好！

感谢我的同事们为此书做出的贡献（以下排名不分先后）：邓雪蓉、耿研、季兰岚、张晓慧、宋志博、李光韬、郝燕捷、周炜、王昱、赵娟、李挺、李嘉欣、高兰、张倩茹、孙晓莹、黄红、王留均、叶夏！

感谢香港风湿病学界的同仁：李家荣、何紫筠！

感谢张辰瑶和杨运琦在本书的英文校对中所付出的辛勤劳动！

此书作为北京大学第一医院风湿免疫科成立十周年的见证。

衷心感谢这些年支持我们发展的各位朋友。

张卓莉

2017 年 8 月 3 日

Preface
Light in the Darkness

I can clearly remember when I was exposed to rheumatology thirty years ago, Chinese rheumatology was only in its starting stage. After over 20 years of continuous efforts, auto-antibody detection, which was in exploration phase by that time, is now very mature and widely used. A variety of reliable methods of auto-antibody detection have been established and the detection process has been standardized, which prepared the prerequisite for the rapid development of rheumatology in China. As we enter the twenty-first century, new imaging techniques for the diagnoses and treatment of a variety of rheumatic diseases are gradually being explored and utilized. In 2003, for the first time I studied musculoskeletal ultrasound during my work in the United Kingdom. In 2007, I worked in the Amsterdam Medical Center, the Netherlands, and applied imaging techniques in daily work. These experiences inspired me to promote the new imaging techniques in Rheumatology in China.

I must admit that promoting imaging techniques in Chinese rheumatology was very challenging after I returned to Beijing in 2008. By that time, there was almost no available information about imaging technology in rheumatology, no ultrasound equipment and no experts in this field in China. Fortunately, we were very fearless. We borrowed ultrasound equipment, we took the lead to apply the technology in our daily care of patients, we never ceased to practice, we sum up our experience and then train young doctors to apply the technology. More fortunately, we met several rheumatologists from Hong Kong and received their enormous and selfless support and help. After nearly two years of preparations, we organized our first nationwide imaging training in rheumatology in 2010. The course was very successful and highly recognized by peers. After that, we continued this training every year. As of today, we have completed over 30 nationwide trainings in total.

After several years of accumulation, we put the standardized operational norms and our own experience into a book, *Musculoskeletal Ultrasound in Rheumatology: Standardized Operation and Application*, which was published in September 2013. It is the first musculoskeletal ultrasound book in rheumatology in China and has provided tremendous help in practical operation. It was so welcomed by peers that every copy quickly sold out.

In recent years, we have completed the musculoskeletal ultrasonic scanning for nearly one hundred thousand patients in our department. We have also carried out a few scientific research projects, trained over a thousand doctors and set up a national imaging group. A couple of our young team members have become EULAR endorsed trainers. With the development of musculoskeletal ultrasound in China as well as the recent progress in the application of musculoskeletal ultrasound worldwide, we feel the urgent need to publish an updated reference book about the musculoskeletal ultrasound for Chinese rheumatologists.

Musculoskeletal Ultrasonography in Rheumatology: Fundamental and Practice is a summary of many years of our clinical experience. This book includes recent advances in musculoskeletal ultrasonography in rheumatology, and therefore has more clinical values. In addition, considering the status quo of rheumatology's development in the Asian-Pacific region and the possible opportunities for more international exchanges and cooperation, we decided to publish a Chinese/English bilingual version.

A decade has gone by since we started exploring the field of imaging in rheumatology. During the past ten years, a variety of imaging techniques have been gradually incorporated into the classification criteria of several rheumatic diseases. We have strong faith that new imaging techniques will be the wings for the diagnosis and treatment of rheumatic diseases to soar toward a new height. I believe imaging in rheumatology will bring light to the darkness and bring wellbeing to more patients, like what autoantibody testing did in these thirty years. I wish for rheumatology development to continue in China!

Thanks to my colleagues for their contributions to this book: Dr. Xuerong Deng, Dr. Yan Geng, Dr. Lanlan Ji, Dr. Xiaohui Zhang, Dr. Zhibo Song, Dr. Guangtao Li, Dr. Yanjie Hao, Dr. Wei Zhou, Dr. Yu Wang, Dr. Juan Zhao, Dr. Ting Li, Dr. Jiaxin Li, Dr. Lan Gao, Dr. Qianru Zhang, Dr. Xiaoying Sun, Dr. Hong Huang, Dr. Liujun Wang and Dr. Xia Ye.

I am also very grateful for the help the two experts from the Hong Kong Rheumatology Association: Dr. Gavin Lee and Dr. Carmen Ho.

Lastly, I thank Chenyao Zhang and Valentina Yunqi-Yang Joseph for diligently editing the English version of the book.

This book is a witness to 10-year establishment anniversary of rheumatology department, Peking University First Hospital.

We appreciate all of you for supporting us throughout these years!

Zhuoli Zhang

August 3rd, 2017

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The Basis of Clinic Ultrasound

第一节　超声波的历史
The History of Ultrasound

人们对声波及其特性的认识源远流长。1912 年泰坦尼克号沉没后，加拿大籍的 Reginald A. Fessenden 发明出第一套声波定位仪器，有助于探测两海里之内的冰山。该仪器在第一次及第二次世界大战中便开始应用于探测敌方的潜水艇。工业上，超声技术则应用于寻找金属结构缺陷，如裂缝及损坏等。

There was a long history since sound wave and its characteristics were discovered. In 1912, the Canadian scientist Reginald A. Fessenden invented the first Sonar-sound navigation and ranging machine to detect icebergs within two nautical miles after the sank of Titanic. This machine started to be applied in detecting enemy submariners in the World War I and World War II. Ultrasound was used in the industrial level to discover the structural flaws of metals, such as fissures or damages.

一、超声波在医学中的早期应用（The Early Application of Ultrasound in Medicine）

最初将超声波技术应用于医学的是维也纳神经科医生 Karl Dussik。他于 1942 年尝试应用超声技术对脑肿瘤进行定位。在 20 世纪 50 年代，剑桥大学的 John Julian Wild 进一步发现了 A 型超声及 B 型超声技术。谈到超声波技术在临床中的应用，不能不提到英国格拉斯哥的妇产科教授 Ian Donald，他在第二次世界大战时接触到有关雷达及超声的技术，之后他在伦敦遇到 John Julian Wild，而后便开展了一系列关于超声波在诊断医学中应用的研究。1958 年，Ian Donald 教授在 *Lancet* 杂志上刊登了使用超声波探查卵巢囊肿的文章。之后，超声波逐渐在产科推广，主要应用于产前诊断胎盘前置、探测早期子宫内的胎儿及测量胎儿头部大小等。

Ultrasound was first applied in medicine by a Viennese neurologist Karl Dussik. In 1942, he tried to locate brain tumors using ultrasound. In 1950s, Professor John Julian Wild of Cambridge University further discovered type A ultrasound which referred to amplitude and type B ultrasound which referred to brightness. Moreover, Professor Ian Donald in the Department of Gynecology and Obstetrics in Glasgow had played an important role in the development of clinical application of ultrasound. He got familiar with radar and ultrasound technology in the World War II, and after meeting Prof. John Julian Wild in London he started a series of study of ultrasound in diagnostic medicine. In 1958, Professor Ian Donald published an article in *Lancet* on the detection of ovarian cyst by using ultrasound. Since then, use of ultrasound in obstetric medicine had become increasingly popular, which including the diagnosis of placenta previa, detecting fetus in early pregnancy and measuring the size of fetal head.

二、肌肉骨骼超声的发展（The Development of Musculoskeletal Ultrasound）

1958 年，K. T. Dussik 发表了首份有关肌肉、骨骼、软骨及关节旁组织的声波特征数据，为肌肉骨骼系统超声的发展奠定了基础。其后的发展则有待超声探头、计算机技术及 B 超的进一步发展才能再上一个台阶。D. G. McDonald 于 1972 年就腘窝囊肿（又称 Baker 囊肿）与下肢深静脉血栓的超声下表现分别做了描述。

In 1958, K. T. Dussik published the first article about ultrasound characteristics of muscle, skeleton, cartilage and adjacent tissues of joint, which lied the foundation for the future development of musculoskeletal ultrasound. Further progress was not made until the evolution of ultrasound probe, computer technology and type B ultrasound. In 1972, D. G. McDonald described the sonographic features of Baker cyst and deep venous thrombosis of lower extremity.

自 20 世纪 70 年代起，肌肉骨骼系统超声逐渐被重视，硬件及成像技术的不断改进和优化成为其中的催化剂。1978 年，P. L. Cooperberg 对类风湿关节炎（rheumatoid arthritis，RA）的病变，如滑膜增生及积液的超声表现进行了描述。1988 年，L. De Flaviis 首次发表了关于类风湿关节炎关节侵蚀的报告。能量多普勒（power Doppler，PD）的出现让炎性疾病的研究工作有了更加有效的工具。

Since 1970s, with the continued improvement of hardware and imaging techniques, musculoskeletal ultrasound had gained increasing attention. In 1978, P. L. Cooperberg described the sonographic appearance of rheumatoid arthritis, such as synovial hypertrophy and joint effusion. In 1988, L. De Flaviis published the first article describing bone erosion of rheumatoid arthritis. Subsequently, the availability of power Doppler technique became a useful tool for the research of inflammatory diseases.

欧洲国家在肌肉骨骼超声的发展中做了很多工作，他们在技术的推进、超声使用的推广及培训、制定超声扫描的基本体位和方法等方面都做出了很多贡献。现在，不仅仅是风湿科，还包括影像科、超声科、骨科、运动医学科、麻醉科、疼痛科及康复科都对肌肉骨骼超声有着浓厚的兴趣。美国风湿病学会在 2012 年的年会上还发表了相关的临床建议。

The European countries had done a lot on the development of musculoskeletal ultrasound; and they contributed to a great extent in the promotion and training of musculoskeletal ultrasound application, as well as standardizing the scanning position and method of different joints. To date, not only rheumatology department, but also other departments including diagnostic radiology, ultrasound, orthopedics, sports medicine, anesthesia, pain clinic and rehabilitation showed a lot of interests in musculoskeletal ultrasound. The American College of Rheumatology had also released specific clinical recommendations on the use of musculoskeletal ultrasound in their annual meeting in 2012.

三、肌肉骨骼超声的发展方向（The Developing Direction of Musculoskeletal Ultrasound）

随着科技的突破，我们深信肌肉骨骼超声会不断发展。三维超声、能量多普勒的优化、成像后的数据分析都是值得关注的发展方向。希望当技术更成熟，仪器的制作成本下调后，更多的医护人员可以给患者提供更经济、更便捷、更准确、更有效的诊治。

With breakthroughs in technology, we believe that musculoskeletal ultrasound will advance further. 3D ultrasound, optimization of power Doppler and data processing of images are the areas of interest for further development. We hope that with more mature technology and lowering of production cost of USG devices, more healthcare workers could provide patients with less expensive, more convenient, more accurate and efficient treatment.

第二节 超声波的基本概念
The Basic Concepts of Ultrasound Wave

一、声波的概念（The Concept of Sound Wave）

声波是一种机械波。声波的产生需要两个条件，一个是声源，另一个是能够传播这种机械振动的介质。声波按频率划分，可分为次声波、声波和超声波。当振动源产生频率为 20 ～ 20 000Hz 的振动，在弹性介质中激起疏密波而传播至人的听觉器官（耳）时，可以引起声音的感觉。这种可以听到的频率范围内的振动称为声振动，由声振动激起的疏密波即为声波。超过 20 000Hz 的声波是超声波。有关声波的几个物理量的概念如下所示。

Sound wave is a mechanic wave. The production of sound wave needs two conditions, one is sound source and the other is the media which could spread the mechanic vibration. On the basis of frequency, sound waves are divided into three types: infrasonic wave, audible wave and ultrasonic wave. When the vibrating source produces a vibration with the frequency between 20 to 20 000Hz, it could raise dilatational wave in elastic media, thus it could spread to human ears and cause the feeling of sound. The vibration in the range of hearing is called audible vibration and the dilatational wave raised by audible vibration is called audible wave. Ultrasonic wave is more than 20 000Hz. Some of the physical concepts about sound wave is as below.

（一）频率（Frequency）

频率是指单位时间内通过介质中某点的完整疏密波的数目，一般以 *f* 表示，单位为赫兹（Hz），1Hz 即每秒振动 1 周（c/s）。

Frequency is the number of complete dilatational waves through a certain point of media during a certain period of time; and it is often represented as *f*. The unit of frequency is Hertz (Hz)，and 1Hz refers to 1 cycle of vibrate per second (c/s).

（二）声速（The Speed of Sound）

声速是指单位时间内声波（包括超声波）在介质中传播的距离，一般用 *C* 表示。声速的快慢与介质的密度及弹性有关，而与声波的频率无关。一般来说，声波的传播速度在气体中较小，在液体中较大，在固体中最大。例如，声速在空气中约为 340m/s，在水中约为 1500m/s，而在金属中则约为 4500m/s。在人体软组织中的声速与在水中相近，约为 1500m/s。

The speed of sound is defined as the distance travelled per unit time by a sound wave as it propagates through an elastic medium which is represented by *C*. The speed of sound depends on the density and elasticity of its media, but does not depend on the frequency of sound. Generally, sound travels most slowly in gases, faster in liquids, fastest in solids. For example, the speed of sound is about 340m/s in air, 1500m/s in water, 4500m/s in medal. The velocity of sound in human soft tissue approximately equals to that in water, which is about 1500m/s.

（三）波长（Wavelength）

声波在传播时，两个相邻的位相相同的质点之间的长度，即声波在一个完整周期内所通过的距离，称为波长，用 λ 表示。波长、声速与频率之间有密切的关系，可用公式表示如下：$C=f\cdot\lambda$。

When sound wave spreads, the length between two adjacent points at the same state of oscillation, in other word, the distance that it covers during one complete cycle, is called wavelength, which is represented by λ. There is close connection between wavelength, the speed of sound and frequency, which could be described as: $C=f\cdot\lambda$.

（四）周期（Cycle）

声波在传播中两个相邻的位相相同的质点(即一个完整波长)之间所经历的时间即为周期，用 T 表示，频率越高者，周期越短。以公式表示：$T=1/f$。

Cycle is the time that sound wave takes to cover two adjacent points at the same state of oscillation (a complete wavelength) and is represented by T. The higher the frequency is, the shorter the cycle is. The relation is described as: $T=1/f$.

二、超声波的物理性能（The Physical Characters of Ultrasonic Wave）

（一）方向性（Directivity）

超声波与一般的声波不同，由于其频率极高，波长很短，远远小于换能器(探头压电晶体片)的直径，在传播时发射的超声波集中于一个方向，类似于平面波，声场分布呈狭窄的圆柱状，声场宽度与换能器压电晶体片的大小相接近，因而有明显的方向性，称为超声束。

The ultrasonic wave is different from other sound waves, for its frequency is extremely high and its wavelength is a lot shorter than the diameter of the transducer (piezoelectric crystal plate of probe). During propagation, ultrasonic wave concentrates in one direction like the plane wave. The distribution of its sound field forms a narrow cylinder column, and the width of sound field is similar to the size of the transducer piezoelectric crystal plate. In this way, the ultrasonic wave has significant directivity, which is called the ultrasonic beam.

（二）反射与折射（Reflection and Transmission）

超声在传播中经过两种不同介质的界面时，由于界面前后介质声速的不同，超声传播的方向将发生变化。一部分能量由界面处返回第一介质，此即反射（reflection），其方向与声束和界面间的夹角有关，反射角和入射角相等。如声束与界面相垂直，即沿原入射声束的途径返回。另一部分能量能穿过界面，进入第二介质，此即折射（transmission），此时，声束方向可能发生改变，其角度大小依折射率而定。声能在界面处反射与折射的总值不变，与入射的能量相等，但反射多少则随界面前后介质的声阻差异而有所不同。

When the ultrasound travels through the surface between two tissues, the propagation direction of the ultrasound will change due to its difference in sound speed in the tissues. Some of its energy will return to the medium it oriented, which is called reflection. The direction of reflection depends on the angle between the sound beam and the surface; and the reflection angle equals to incident angle. If the beam goes vertically into the surface, it will return along the way it comes. Other parts of its energy can penetrate the surface into the second medium, which is called transmission. In this way, the direction of the sound beam might change, and the angle of changing depends on the transmission rate. In the surface, the sound energy of reflection and transmission together remains, and is equal to incident energy. However, the amount of reflection is in accordance with different acoustic impedance between the two mediums.

声阻（acoustic impedance）即声阻抗率，等于介质的密度与超声在该介质中传播速度的乘积。两介质声阻相差越小，则界面处反射越少，透入第二介质越多；反之，声阻相差越大，则界面处反射越强，透入第二介质越少。

Acoustic impedance is also called acoustic impedance rate, and it equals to the density of media multiply by ultrasonic velocity in the certain media.The smaller the acoustic impedance difference of the two media is, the less reflection in the media and the more transmission into the second medium. Otherwise, the larger acoustic impedance difference of the two media is, the more reflection in the media and the less transmission into the second medium.

（三）吸收与衰减（Absorption and Attenuation）

声波的衰减分为两种：距离衰减和吸收衰减。声波在前向传播过程中因发生反射、折射及散射等现象使声能随着距离的增加而逐渐减弱，此种现象称为距离衰减。声波在介质中传播时，使分子产生振动，振动的分子将声能传播给其他分子，当声波穿过介质时，由于“内摩擦”或“黏滞性”而使声能逐渐减小，声波的振幅逐渐减低，介质对声能的此种作用即为吸收，这种在介质中传播时出现的衰减称为吸收衰减。

The attenuation of sound wave is categorized into two kinds: range attenuation and absorptive attenuation. When sound wave disseminates forward, reflection, refraction and scattering weakens the sound energy as the distance grows. This phenomenon is called range attenuation. When sound wave propagates in media, the molecules vibrates, and these molecules can transmit sound energy to other molecules. While the inner friction or viscosity weakens the sound energy, the amplitude of sound wave gradually decreases. The absorptive effect of media to sound energy is called absorption; and the absorption during propagation in media is called absorptive attenuation.

吸收和衰减的程度与超声的频率、介质的黏滞性、导热性、温度及传播的距离等因素有密切关系。

The absorption and attenuation level depends on factors including the frequency of ultrasound, the viscosity, thermal conductivity, the temperature of media and communicating range.

超声波在生物介质中的吸收程度主要依赖于介质的特性和超声的频率。总体来说，介质中水的含量越大，超声波吸收越少；超声频率越高，吸收越大。声能吸收之后，能量减小，显示的反射亦较弱，但经电路补偿之后，仍能清晰观察。

The absorption level of ultrasonic wave in biological media is associated with characters of media and ultrasonic frequency. Generally speaking, the more water that the media contains, the less absorption ultrasonic wave is. When the frequency of ultrasound is higher, the absorption is greater. After the sound energy is absorbed, the reflection became weaker due to a weaker energy. But after the compensation of electrocircuit, it can still be observed clearly.

（四）多普勒效应（Doppler Effect）

多普勒（Doppler）效应是奥地利物理学家 Doppler 在观察星球运动时发现的，即当星球与地球之间存在相对运动时，所接收到的光波频率会与发射频率出现差异。由此频率差异（频移）可推算相对运动的速度。当超声用于血流测定时，血细胞的后散射能量虽小，但亦可产生多普勒效应。多普勒诊断仪可以截取这些信号，并分析血细胞运动的速度。用于诊断的超声频率为 2 ～ 10MHz，由细胞运动而产生的多普勒频移一般为 0.5 ～ 10kHz。根据血细胞的频移大小（f_d）即可计算出血液流速和血流量。

Doppler effect was discovered by Austrian physicist Doppler when he was observing the star movement. He found that when the star was moving relatively to the Earth, the receiving light wave frequency and the launching frequency appear to be different. According to the frequency difference, we can calculate the velocity of the relative movement. When ultrasound is used to detect the blood flow, although the back-scattering power of the blood cell is weak, it can still create the Doppler effect. The Doppler diagnostic apparatus can capture these signals and analyze the velocity of the blood cell movement. We use the 2-10MHz to diagnose, the movement of the cell can create the frequency shift 0.5-10kHz.According to the frequency shift (f_d), we can calculate the blood flow velocity and the blood flow volume.

利用多普勒效应进行超声检测，将多普勒频移大小在零线上下显示为波幅高低的曲线，此即频谱多普勒（spectral Doppler），包括脉冲型和连续型两种类型。在进行超声脉冲多普勒检测时，将扫描线上各点的频移方向、大小，均以伪彩色编码红、蓝、绿等颜色显示，此即彩色多普勒（color Doppler）。频谱多普勒在观察血流方向与速度方面有重要意义，而彩色多普勒检测则能显示血流的方向、速度、动态、有无反流与分流等多种信息。超声多普勒技术的临床应用为心血管疾病的无创检测带来了革命性的变化。

Using the Doppler effect to conduct the ultrasound test, the Doppler frequency shift can show its size through the amplitude above or below the zero line, which is called Spectral Doppler, including pulse mode and the continuous mode. In the pulse mode Doppler test, the frequency shift direction and size of the point on the scanning line are showed by the pseudo color coding using the colors of red, blue, green and so on, which is called the Color Doppler. Spectral Doppler is very important in observing the blood flow direction and the velocity, but the Color Doppler can show the direction, the velocity, the trends and regurgitation or bypass or not. The use of the ultrasound Doppler technique in the clinical work makes revolutionary changes in the noninvasive detection of the heart disease.

（五）散射与背向散射（Scatter and Back Scatter）

当超声波束遇到大于波长的、声阻不同的组织界面时，仪器通过接收反射波来显示图像。当超声波束遇到远远小于声波波长且声阻不同的界面时则会产生散射，其能量向各个方向辐射，朝向探头方向（与入射角成 180°）的散射波称为背向散射或后散射（back scatter）。目前，检测背向散射的信号是对提取自相关区域射频信号的功率谱（不同频率情况下散射波强度的平方值）进行积分，此积分可以曲线方式或二维方式实时显示。根据背向散射积分计算背向散射积分指数、背向散射心动周期变化幅度和跨壁背向散射积分梯度等，可以评价人体组织特征。利用背向散射信号进行组织定征将是一种特异、敏感和准

确的方法。

When ultrasound acoustic beam meets tissue planes with bigger wavelength and different acoustic resistance, the instrument shows image by receiving reflected waves. When ultrasound acoustic beam meets tissue planes with the wavelength far less than the ultrasound and the different acoustic resistance, the energy will radiate into different directions, the scattered wave towards the probe is called back scatter (the angle of incidence is 180°).At present, to test the signal of the back scatter is to collect the power spectrum of the radio-frequency signal in the relevant zone (the square of the intensity of the scatter wave in different frequencies) to integrate. This integration can real-time show in the way of the curve method or the two-dimensional way. To calculate the back-scatter integration index, the back scatter cardiac cycle rangeability and the transmural back scatter integration gradient according to the back scatter integration is able to evaluate the characteristics of human tissue. It is a specific, sensitive and accurate way to evaluate the characteristics using the back-scatter signal.

（六）非线性传播（Non-linear Transmission）

声波的传播过程实际上是非线性传播过程，但为了简化问题，通常假定其为线性传播。声源所发射的声波在介质中传播遇到界面时，可发生反射和折射，此即声波在介质中的线性传播。当声波遇到不规则界面（组织）时，其传播可发生波形畸变、谐波成分增多和衰减系数增大现象，声波的这种传播方式称为非线性传播。在传统的超声信号处理中，声波的非线性信号往往被忽略。随着电子和计算机技术的迅速发展，超宽频探头、宽频数字声束发射器、扩展信号处理技术及频率融合技术的开发，声波非线性信号的研究工作取得了很大的进展。

The process of the wave transmission is actually non-linear. However, in order to simplify the problem, we usually assume it is linear. In the process of the wave transmission, when the wave meets the interface, the reflection and the refraction may take place. This is a linear transmission in the medium.When the wave meets the irregular interface (tissue), the harmonic component increases, the attenuation coefficient gets bigger and the waveform distortion may happen, which makes the transmission non-linear. In the process of the traditional ultrasonic signal, the non-linear signal is usually ignored. As the electronic and computer technologies develop, as well as the development of the ultra-wideband probe, the broadband digital beam emitter, the expand signal processing technology and the frequency fusion technology, the research of the non-linear signal made much progress.

三、人体组织声学类型（Acoustic Type of the Human Tissue）

如前所述，超声在介质中传播时遇到界面即发生反射，反射率的大小与界面前后两种介质声阻差异的多少有密切关系。人体有各种不同的组织，结构复杂，其声学特征有很大不同。现将超声检查时经常探及的组织器官和有关物质的密度、声速与声阻抗值等列表如下（表 1-1）。

As we have mentioned, when the ultrasound meets the interface during the transmission, the reflection will happen. The reflection depends on the difference of acoustic impedance of the two materials at reflective interfaces. The Human body has various kinds of tissues; the structure is complex; and have distinct acoustic characteristics. The often-probed tissue organ, the relevant density, the sound velocity and the acoustic impedance are listed as follows (Table 1-1).

表 1-1　人体组织密度、声速及声阻抗数值表

Table 1-1　The density，the sound velocity and the acoustic impedance of the human tissues

组织器官 tissues and organs	密度 density（g/cm^3）	声速 sound velocity（m/s）	声阻抗 acoustic impedance（$\times 10^5 g/mm^2 \cdot s$）
血液 blood	1.055	1570	1.656
脑脊液 cerebrospinal fluid	1.000	1522	1.522
大脑 cerebrum	1.038	1540	1.599
小脑 cerebellum	1.030	1470	1.514
体液 body fluid	0.9973	1495	1.492
肌肉（均值）muscle（mean value）	1.074	1568	1.684
肝脏 liver	1.050	1570	1.648
软组织（均值）soft tissue（mean value）	1.016	1500	1.590
脂肪 fat	0.955	1476	1.410
骨骼 bone	1.800	3380	6.084

我们根据声阻相差大小与组织结构内部的均匀程度等，试将人体组织、器官等的声学类型分为 4 种，以供超声检查时参考。

We divided human tissue and organs into four kinds according to the acoustic impedance and the uniformity coefficient of the tissue in order to provide a reference in the ultrasonic examination.

（一）无反射型（Areflexia）

所有液态物质（包括血液、脓液、胆汁、腹水、尿液等）质地均匀，内无声阻有差异的界面，即使人为地假设存在一个界面，但因其前后为同一物质，声阻值相同，代入上述公式后，其反射系数也为 0，故超声经过时，在相应区域无波反射。用低灵敏度检查时呈现暗区，提高灵敏度（加大增益）时仍如此。这种反射类型是液体的特点，故称无回声区或液性暗区。由于反射少、吸收少，声能可很好地透射与传导，故在其后壁处反射有增强现象，如心腔内血液、胆囊内胆汁等均属于无反射型。

All liquids (including blood, pus, bile, ascites, urine and so on) are uniform texture. All interfaces have the same acoustic impedance, even if we assume an interface with a different acoustic impedance, but because it is the same substance, the acoustic impedance stays the same, so when we calculate using the formula above, the reflection coefficient is also 0, thus when the ultrasound passes, there is no reflection. It shows dark field when using the low sensitive detection, when we increase the sensitivity (enlarge the gain), it is still the same. This reflection type is the characteristic of the liquids, so we call it no echo area or opaque dark area of the