White paper – Introduction to MRI simulation and MRI simulators

This is the second whitepaper in a series of whitepapers on simulators, realism, performance and comprehensiveness.

Introduction

In an environment of reduced access to real MR scanners for educational and research purposes, the availability of realistic MR simulators is key to the improvement of the overall educational process and the reduction of the conception-to-completion time for new products in the MR field.

Over the last few years, Corsmed has focused on building the most powerful, comprehensive, and realistic MR simulation platform in the world. The high performance, availability and realism of the simulation platform allow its users to configure and try advanced MR protocols without being limited by traditional constraints such as time, accessibility and availability of both real MR scanners and subjects (healthy volunteers and patients).

Corsmed's MR simulation platform is an enabling tool for MR practitioners that ultimately improves the learning via experience and training and, in turn, patient care and safety. At Corsmed, our development team is constantly working on improving the MR simulator by adding more realism to the simulated MR images, increasing its performance, and expanding its capabilities to have a comprehensive platform that covers standard clinical cases.

In this comprehensive guide, we delve into the world of MRI simulators and their significant role in training, research, and efficiency improvement. MRI simulators are powerful tools that replicate the scanning process, providing trainees with a safe and controlled environment to develop their skills. We explore various aspects of MRI simulators, from their types and capabilities to their impact on learning, experimentation, and workflow optimization. By the end of this paper, you will have gained a deeper understanding of MRI simulators and their potential to transform the field of MRI.

There are 5 chapters outlined below:

- Chapter 1 – What is an MRI simulator?
- Chapter 2 – The most important aspect in choosing an MRI simulator
- Chapter 3 – Different types of MRI simulators for training and education
- Chapter 4 – How to implement MRI simulators
- Chapter 5 – The remarkable speed of an MRI simulator

Chapter 1:
What is an MRI simulator?

MRI simulators play a crucial role in both training personnel and aiding patients who may experience anxiety or fear during MRI scans. In this blog post, we will explore three different types of MRI simulators and discuss their purpose and impact on organizations and patients.

There are three different types of MRI simulators: Physical, Software, and Radiotherapy.

Physical MRI simulators

Physical MRI simulators serve a dual purpose: training personnel and helping patients overcome fear or anxiety associated with MRI scans. These simulators replicate the physical environment of an MRI scanner, allowing individuals to become more accustomed to the experience. For personnel, it provides hands-on training to improve their patient handling skills, while for patients, it offers a comforting environment to become more accustomed to the scanning process, reducing stress and improving the overall scanning experience.

Figure 1 - A physical MRI simulator to help train patient positioning

Software MRI simulators

Software MRI simulators primarily focus on training personnel. These simulators use virtual environments to recreate the MRI scanning process. They offer realistic scenarios and allow trainees to practice various procedures, learn proper techniques, and familiarize themselves with the software and controls of an MRI scanner. Software simulators enhance the efficiency of training programs, ensuring that personnel are well-prepared for real-world scanning scenarios.
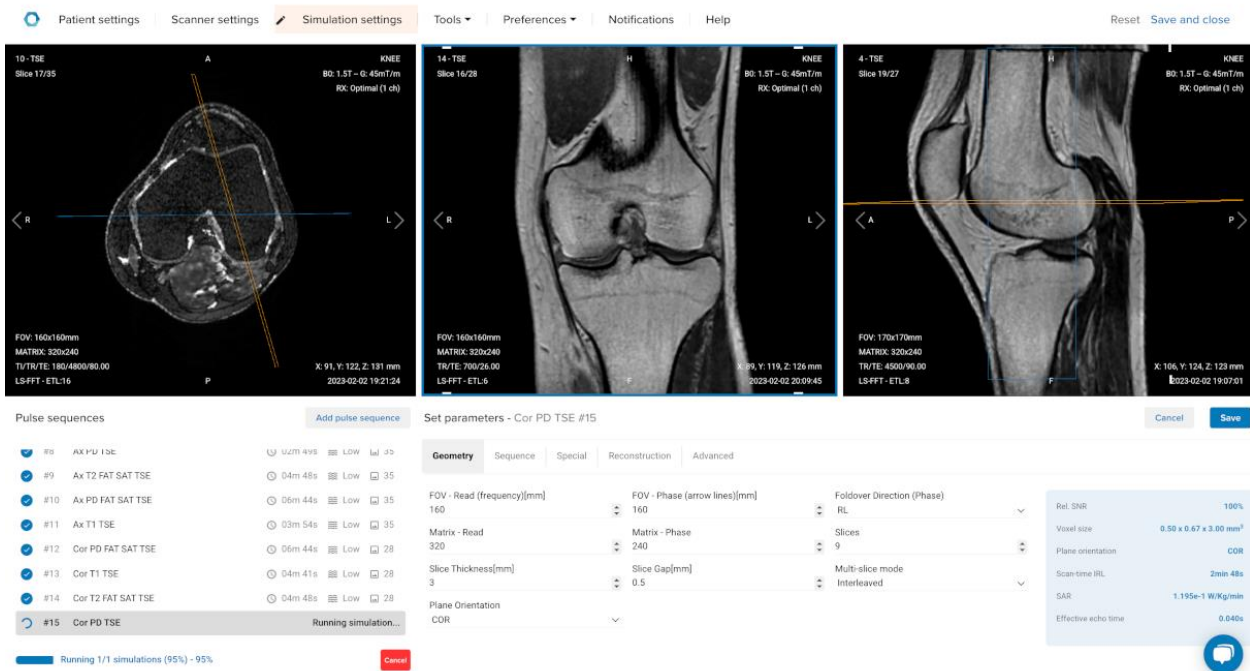

Figure 2 - Corsmed's MRI simulator - A software MRI simulator to help trainees and students of all MRI disciplines to better, faster and easier learn MRI

Radiotherapy MRI simulators

Radiotherapy MRI simulators serve a specific purpose in the field of oncology. They combine the capabilities of an MRI scanner with radiotherapy planning tools. These simulators enable accurate and precise planning for radiotherapy treatments by incorporating MRI images. They assist in determining the optimal treatment parameters and target areas while minimizing radiation exposure to healthy tissues.

Corsmed's MRI simulator is the only simulator in the world which combine true MRI simulations, vast arrays of real-world MRI features, on industry aligned interfaces, all to provide a truly one-to-one experience for full transferability of simulator acquired skills.

Conclusion

MRI simulators have revolutionized the training process for personnel and improved patient experiences. Physical MRI simulators alleviate anxiety and fear, software simulators enhance personnel training, and radiotherapy MRI simulators aid in precise treatment planning. Understanding the different types of MRI simulators and their respective purposes can help organizations and individuals make informed decisions regarding their implementation.

Chapter 2:
The most important aspect in choosing and using an MRI simulator

When selecting and utilizing an MRI simulator, it is crucial to consider the desired real-world effects. In this blog post, we will explore the significance of choosing an MRI simulator that provides training experiences transferrable to the actual real-world MRI scanning environment.

The key question is: "Are trainees becoming better at using the training software, or better at MRI scanning itself?"

Translating training to the real world

The ultimate goal of using an MRI simulator for personnel training is to improve their scanning abilities in real-world scenarios. It is essential to select a simulator that accurately emulates the MRI scanning process as it is done in the clinic, including patient positioning, protocol and sequence selection, parameter design and trade-offs, and last image interpretation. By ensuring a high level of realism, the simulator can effectively prepare trainees for actual MRI scanning.

The training software vs. scanning skills

A common concern is whether trainees become proficient in operating the training software, or actually gain expertise in MRI scanning. While seeing your results and scores improve in the training software may be exciting, it should not overshadow the primary objective of enhancing scanning skills. A well-designed MRI simulator should allow the trainee or student to train and practice in a safe setting, and build skills which are directly transferable to the real world, i.e. acquire the essential skills and knowledge required for successful MRI scans.
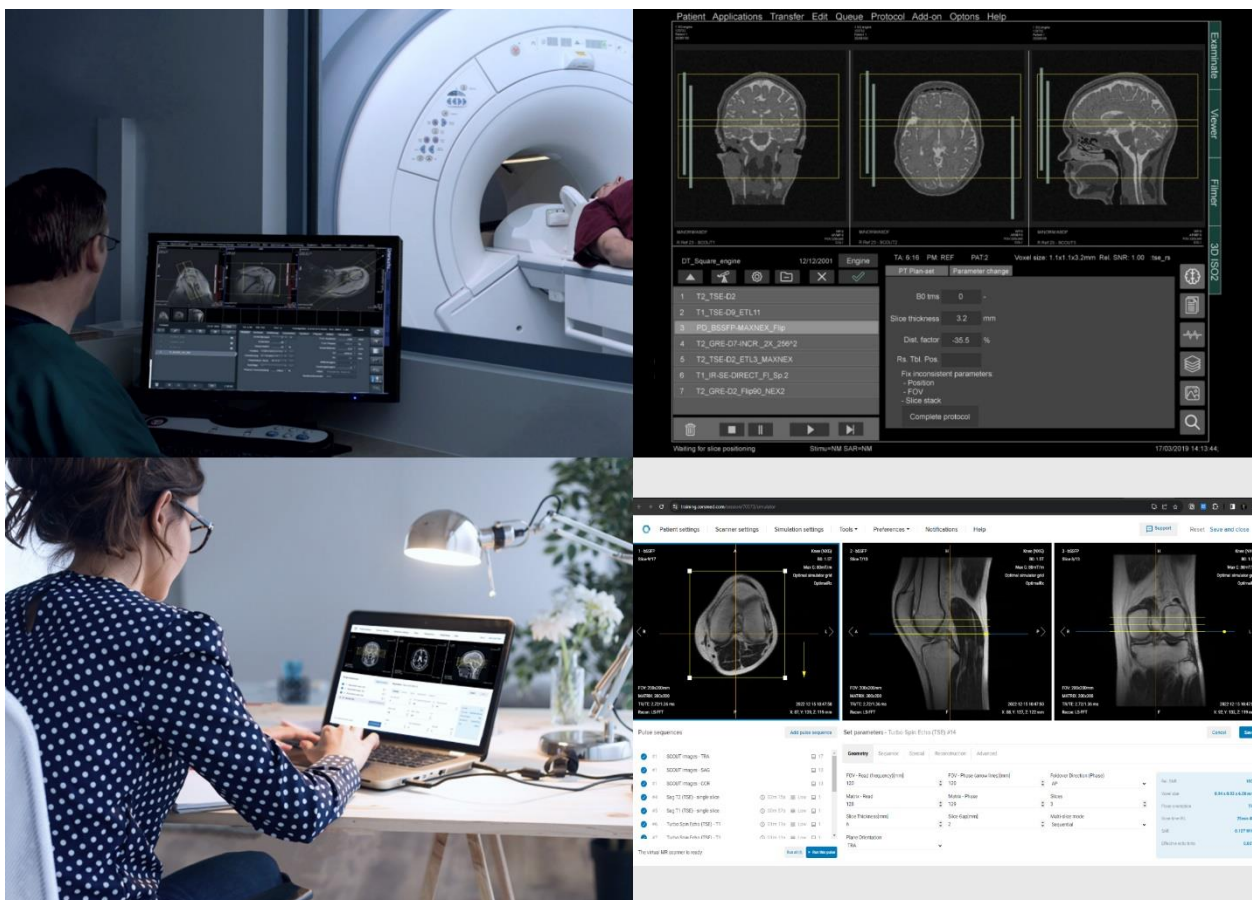
Figure 1 - A real-world MRI scanner in the control room (top left and top right), and Corsmed's MRI simulator (bottom left and bottom right)

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Conclusion

When choosing and utilizing an MRI simulator, organizations and individuals should prioritize simulators that offer training experiences closely aligned with real-world MRI scanning. It is essential to recognize the distinction between becoming proficient in the training software and acquiring the necessary real-world scanning skills. By focusing on simulators that facilitate skill transferability, organizations can maximize the effectiveness of training programs and ensure improved scanning outcomes.

Chapter 3:
Different types of MRI simulators for training and eductation

In the realm of MRI simulators, there are different types of software-based solutions that aim to replicate the scanning process. However, not all simulators are created equal. In this blog post, we will explore the three main types of software MRI simulators and highlight the significance of using a true MRI simulator for comprehensive training and practice.

In short, there are 3 categories of MRI simulators, which all have different sub-types, and come with different capabilities. These are the Image bank simulators, the Closed-form simulators, and the True MRI simulators. These categories are explored below.

Image bank simulators

Image bank simulators come in two forms: pure image bank simulators and MIPS/MPR-based simulators. These simulators rely on pre-acquired images to mimic the scanning process, utilizing various tricks and techniques.

Pure image bank simulators load pre-existing images that closely resemble what trainees attempt to create in the interface. However, this approach poses a risk of providing incorrect images if the database is not infinitely large.

MIPS/MPR-based simulators, on the other hand, employ pre-acquired isotropic 3D images and utilize multi-planar reformatting techniques to create new slice positions. While this approach provides accurate images, it only covers the slice positioning part of the MRI scanning process, which is a small and usually a less important part.

Ultimately, image bank simulators offer a limited learning experience that may negatively impact students' learning and patients' health, particularly when it comes to understanding trade-offs and practicing running the scanner.

Closed-form simulators

Closed-form simulators are the first type of simulators that can genuinely be considered simulators. They attempt to generate the signal and image from scratch using mathematical estimates. However, these estimates are confined to a few pulse sequences and address basic MR physics concepts describable by analytical expressions.

Although closed-form simulators offer more degrees of freedom compared to image bank simulators, the simulated MR images are far from the true simulated MR images and lack reliability

for teaching, training, and practice purposes. While these simulators are fast and favored by researchers working with vast amounts of data and experiments, they fall short when it comes to training students on running protocols in real scanners.

True MRI simulators

True MRI simulators represent the pinnacle of simulation technology, closely mirroring the functioning of real MRI scanners. They simulate every image from scratch, just as real scanners do.

A true MRI simulator computes and measures the MR signal for each spin within every voxel, for the selected anatomical volume, and for each time step of the pulse sequence. This comprehensive measurement captures the evolution of the MR signal throughout the application of the pulse sequence, allowing the construction of K-space (raw data) and subsequent reconstruction of the MR image through an inverse Fourier transform (or other reconstruction technique).

With a high-quality true MRI simulator, the resulting images should be identical to those produced by real scanners when provided with the same inputs, parameters, patients, and sequences.

True MRI simulators are the only reliable option for training and education in running the scanner, setting up protocols, and making trade-offs in parameters.

The Corsmed MRI simulator

Corsmed's MRI simulator is the only simulator in the world which combine true MRI simulations, vast arrays of real-world MRI features, on industry aligned interfaces, all to provide a truly one-to-one experience for full transferability of simulator acquired skills.

Conclusion

When it comes to training and practice in the field of MRI, selecting the right simulator is of paramount importance. Image bank simulators and closed-form simulators offer limited capabilities and may not accurately replicate the complexities of MRI scanning. On the other hand, true MRI simulators provide the most reliable and comprehensive training experience. At Corsmed, we are proud developers of the world's most sophisticated True MRI simulator, available on demand in the cloud. By harnessing the power of true MRI simulation, trainees can gain a deep understanding of trade-offs, parameter effects.

Chapter 4:
How to implement MRI simulators, and tips for success in training

Implementing MRI simulators requires planning and consideration to ensure a seamless integration into training programs. In this blog post, we will explore essential steps to successfully implement MRI simulators and maximize their impact on trainees and organizations.

Implement early

Introducing MRI simulators early in the training process is crucial for optimal skill development. By incorporating simulators at the beginning of training programs, trainees have the opportunity to familiarize themselves with the technology and workflow. Early implementation allows for gradual skill progression and a smooth transition from simulator training to real-world scanning.

Ensure proper training for personnel

To achieve the desired training outcomes, it is vital that personnel guiding trainees and students are well-versed in operating the simulator. Educators and trainers should receive comprehensive training themselves, enabling them to effectively teach trainees and provide guidance throughout the simulation process. This ensures consistency in instruction and enhances the overall learning experience.

Follow-up and Evaluate Effectiveness

After implementing an MRI simulator, it is essential to monitor and evaluate its effectiveness in real-world scanning scenarios. Regular follow-up assessments and feedback from trainees can provide valuable insights into the simulator's impact on skill development and performance improvement. This feedback loop allows organizations to make necessary adjustments to training programs and ensure the simulator is meeting its intended objectives.

Continual professional development (Continuing education)

MRI technology and protocols are continually evolving. Therefore, it is crucial to incorporate ongoing professional development and refresher training for personnel using the simulator. This ensures that they stay up to date with the latest advancements, maintain their skills, and provide trainees with accurate and relevant instruction.

Conclusion

Implementing MRI simulators requires a thoughtful approach and commitment to ongoing training and evaluation. By introducing simulators early, providing comprehensive training to personnel, and monitoring their effectiveness, organizations can optimize the benefits of MRI simulator integration. Ultimately, a well-implemented simulator enhances the skills of personnel, improves patient experiences, and contributes to the overall success of MRI scanning operations.

Chapter 5:
The remarkable speed of an MRI simulator

When it comes to MRI, time is always of the essence. In general MRI training, access to scanners is usually limited, which means that any training on the scanners needs to be productive. This is a common reason why MRI simulators are preferred for training; there is no need to block a scanner and patient access. But more so, using MRI simulators for training brings another benefit – MRI simulators' exceptional speed allows for incredibly rapid training, research and improvement. This blog post explores just how fast the Corsmed MRI simulator is, and what such speeds lead to for educators, trainees, and researchers.

The speed of the Corsmed MRI simulator

The Corsmed MRI simulator offers a significant advantage in speed, revolutionizing the way experiments and training sessions are conducted. Compared to running the same experiments on a real MRI scanner, the simulator operates at an impressive pace, approximately 12 times faster*. This dramatic reduction in time enables users to achieve results swiftly and efficiently, maximizing productivity and accelerating the learning process.

The time-saving benefits of the MRI simulator are nothing short of remarkable. By running experiments on the simulator, users can eliminate more than 90% of the time it would typically take on a real MRI scanner. What might have previously consumed days of practice can now be accomplished in a few hours. This streamlined efficiency frees up valuable resources and allows users to focus on analyzing results, refining techniques, and gaining insights that would otherwise be hindered by time constraints.

The value of fast MRI simulations

The speed of the MRI simulator translates into significant advantages for educators, trainees, researchers and medical professionals. Rapid MRI simulations provide a multitude of benefits, including:

- **Increased learning opportunities:** With shorter experiment durations, users can get much more scans in their experience, and engage in a higher number of practice scenarios. This enhanced frequency and exposure enables accelerated learning and proficiency development, ultimately leading to improved performance in real-life scanning environments.
- **Faster experiment iteration:** The efficiency of the simulator allows for quick iterations and modifications of experimental parameters. Researchers can explore different scenarios,

test hypotheses, and fine-tune protocols with ease, facilitating the discovery of optimal imaging strategies.

- **Enhanced protocol development:** Fast MRI simulations empower users to evaluate a wide range of imaging protocols within a compressed timeframe. This enables comprehensive comparisons of different sequences, parameter settings, and imaging strategies, facilitating informed decision-making and protocol optimization. Ultimately, this leads to scanning operations to do more with less, and get cheaper, faster and better results in the scanning room.

Further quantification of MRI simulation speed (per sequence breakdown)

To showcase the significant time advantage of the MRI simulator, we have included a figure depicting the time required for approximately 20 MRI sequences. Each sequence is represented by two bars, one for the time to run on a real MRI scanner (left, light blue), and one for the time to run on our MRI simulator (right, dark blue). The visual comparison vividly portrays the remarkable speed of the MRI simulator, highlighting its ability to accelerate experimentation and training.
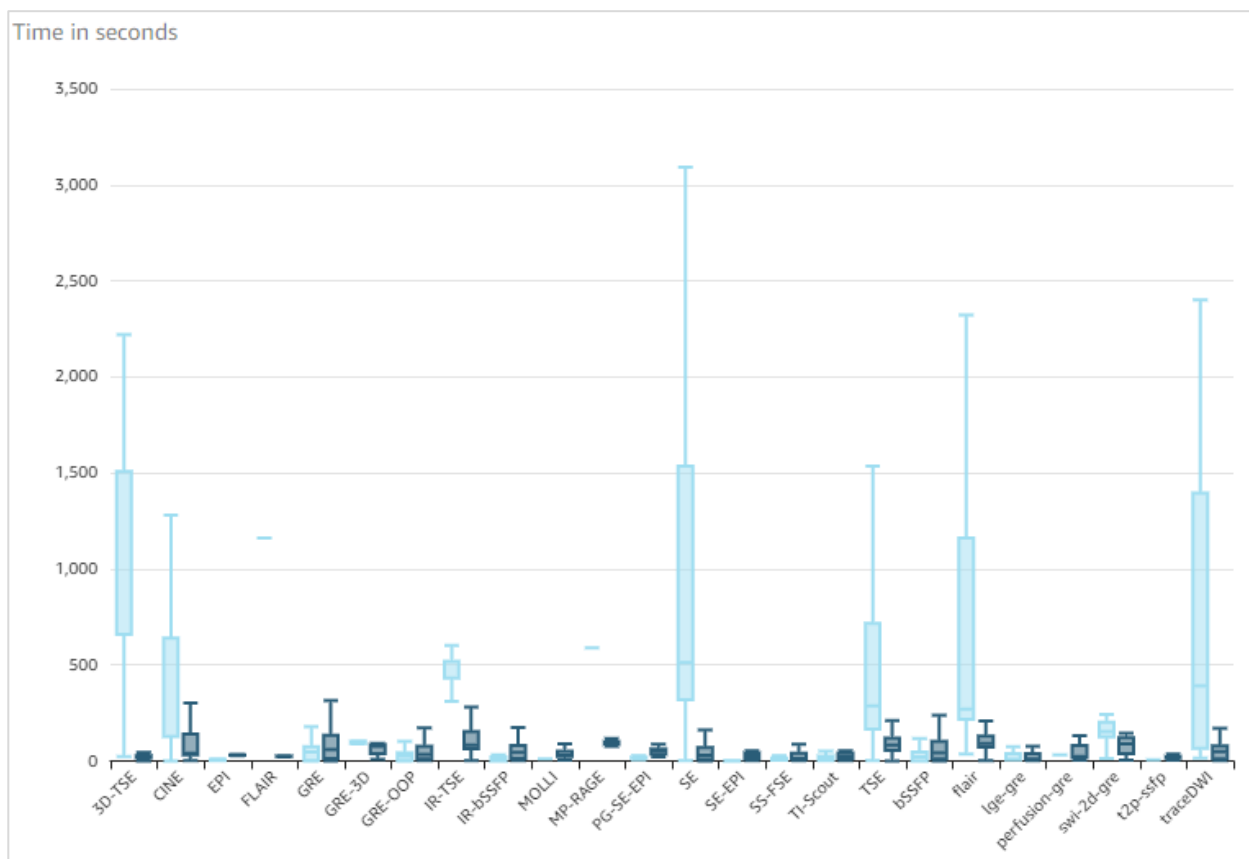

Figure 1 - A comparison of sequences ran on the Corsmed MRI simulator, and their corresponding times in the simulator and a real MRI scanner. Real scanner time in the right bars (light blue), simulator scan time in the left bars (dark blue). The times reflect average times for a series of sequences ran by Corsmed users during spring 2023.

Conclusion

In the fast-paced world of MRI experiments and training, efficiency is key. The Corsmed MRI simulator offers an exceptional speed advantage, operating at approximately 12 times the pace of a real MRI scanner. The time savings achieved through simulation enable users to conduct experiments, train personnel, and optimize protocols in a fraction of the time it would take on a real scanner. This accelerated workflow unlocks unparalleled efficiency, and ultimately faster, cheaper and better MRI.

Notes

* The actual speed up depends on the experiment set-up, it can be faster and slower, but the average is 12x

Summary & conclusion

In this white paper, we have explored the world of MRI simulators and their transformative impact on the field of MRI. We have learned about the different types of simulators and the significance of choosing a true MRI simulator for comprehensive training. We have discussed the essential steps for successful implementation, the benefits of simulator speed, and the opportunities for increased efficiency and productivity.

MRI simulators offer a unique and valuable opportunity for trainees, educators, and researchers to develop skills, refine techniques, and optimize protocols. By incorporating simulators into training programs and leveraging their capabilities, organizations can enhance learning outcomes, improve patient experiences, and drive advancements in MRI scanning.

As technology continues to evolve, MRI simulators will undoubtedly play an increasingly critical role in the future of MRI. By staying at the forefront of simulator advancements and embracing their potential, we can shape a future where MRI scanning is even more precise, efficient, and accessible.

Thank you for joining us on this journey through the world of MRI simulators. We hope this booklet has provided you with valuable insights and inspiration for leveraging the power of MRI simulation.

If you have any questions or want information of any kind, please reach out to Corsmed, either on the website or info@corsmed.com.