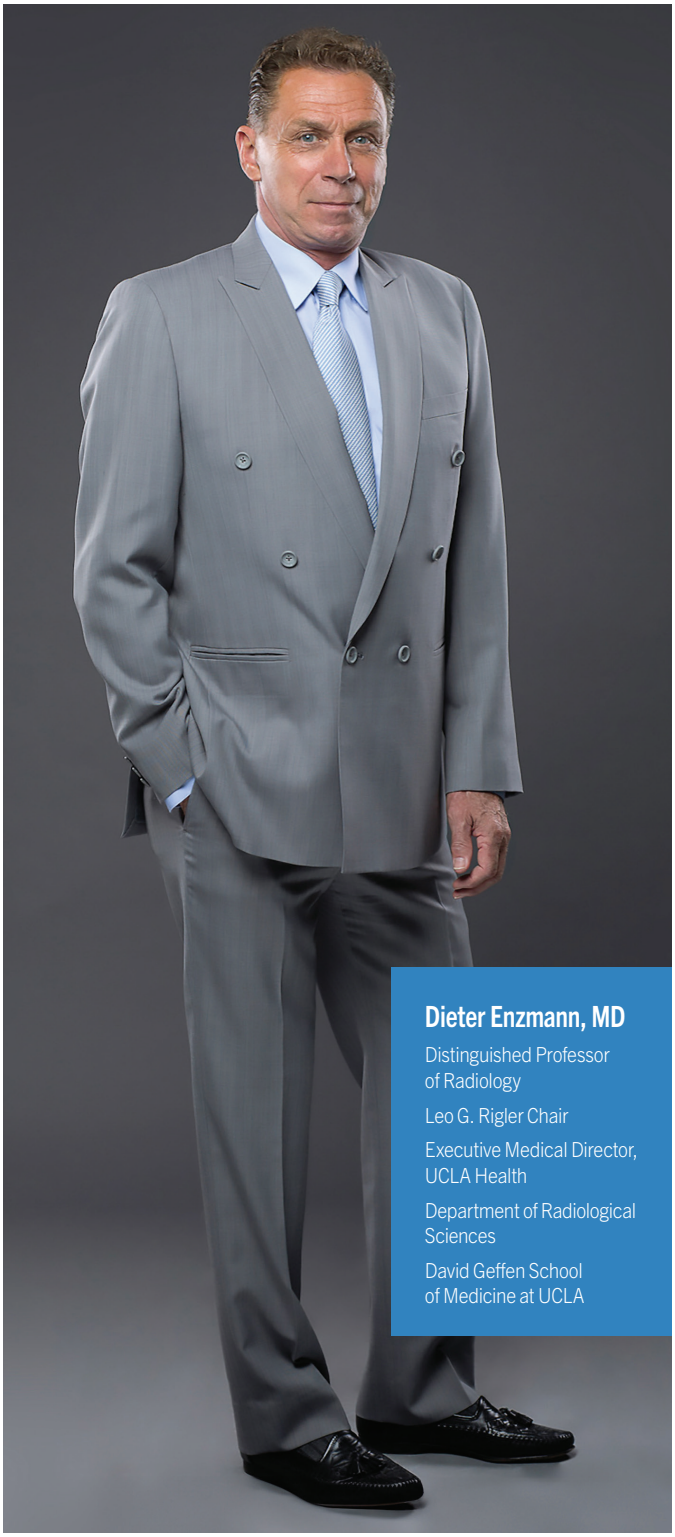
Chair's Message

This final *UCLA Radiology Newsletter* editorial takes a conceptual look at the evolution of radiology, drawing parallels to key features of the First and Second Industrial Revolutions. This helps to explain how radiology has grown into a successful, large-scale imaging service. As these features unfold again in the Third Industrial Revolution, we gain insights into radiology's future.



Dieter Enzmann, MD

Distinguished Professor of Radiology

Leo G. Rigler Chair

Executive Medical Director, UCLA Health

Department of Radiological Sciences

David Geffen School of Medicine at UCLA

The First Industrial Revolution's pivotal feature was the separation of production from consumption. Before this, a blacksmith would make pairs of horseshoes ordered individually by customers who often stood by during production. The introduction of steam power began replacing human muscle, allowing production to scale up independently. Instead of a blacksmith hammering out individual horseshoes, large mechanical machines driven by steam could stamp out thousands of horseshoes independent of individual orders. This separation of production and consumption ushered in economies of scale because each incremental horseshoe made by machines cost less. Steam power scaled up production in manufacturing significantly, transforming the world economy from centuries of an essentially flat GDP into one with a sharp upward spike. Expansion of this concept of separating production from consumption in the First Industrial Revolution changed the entire world. It took a while for it to influence radiology.

Early radiology did not benefit from this concept because production was not separated from consumption. Common GI fluoroscopic studies like upper GIs, barium enemas, myelography and even angiography resembled the blacksmith model. Much of early radiology resembled the pre-First Industrial Revolution model.

The Second Industrial Revolution was characterized by the use of electricity and computers. This started the separation of the production of radiology information work output from consumption. Radiology information work output began to scale up beyond individual radiologist brain power using computer power, beginning to grow at a rate akin to Moore's Law. This marked the beginning of radiology becoming a larger-scale business.

Further innovations in the Second Revolution allowed radiology to expand the separation of production concept with CT and MR technologies. This not only increased radiology information work output but also profitability. Yet the separation was not as complete as the blacksmith model, where the machine's output could be in the thousands without any link to the blacksmith. In radiology, the separation was partial, as CT and MR production was still linked to the radiologist brain power.

Radiology's production of information work output surged in the Second Industrial Revolution when digital imaging technologies separated production from consumption. For instance, doubling or tripling CTA or MRA vascular information work output didn't require doubling or tripling of radiologist brain power units that would have

been required had vascular information needed to rely on the blacksmith model of performing lengthy cerebral angiographic procedures to generate the same amount of information work output. CTAs and MRAs produced more information work output by their separate production process in contrast to a film- and fluoro-based of cerebral angiography with a one-to-one relationship with radiologists similar to the "blacksmith" model. The full First Revolution concept of complete separation was not yet achieved.

Adding radiologists to a group increases their number and aggregate work output, but this type of size and scale does not achieve true economies of scale. Adding an incremental radiologist still requires adding high-cost radiologist brain power. Forming a national group of 1,000 radiologists to generate a large amount of radiology information work output increases scale in numbers, but a roughly one-to-one relationship between the radiologist "brain unit" and radiology information work output remains, as does the associated radiologist brain power cost. This type of scale produces limited economies of scale. Further separation of work output production from the radiologist brain unit is required, where increments in radiology production output come at a cost lower than that of a full radiologist brain unit.

Currently, there remains a roughly linear relationship between radiologist brain units and radiologist information work output. More radiology information work output requires more radiologist brain units. This is set to change with the Third Industrial Revolution driven by GPU power and generative AI (gen AI) because it will allow for further separation of radiology information work output using gen AI "thinking units" from radiologist brain units. Those gen AI/GPU units can produce more horseshoes without blacksmiths, i.e., radiologists. Moreover, those "gen AI/GPU thinking units" can far exceed the number of "radiologist thinking units," working day and night by a thousandfold or more. Gen AI/GPUs scale up much more and faster than the radiologist's brain units. When radiologic information work output is driven by "gen AI/GPU brain units" rather than by "radiologist brain units," whole new production curves are created. The conceptual lesson from the First Industrial Revolution will finally have fully been absorbed into radiology.

The Third Revolution will be based on completely separating the production of cognition from the radiologist brain units to gen AI/GPU brain units, with the latter able to achieve enormous scale. Just like the historical role of steam power, "gen AI/GPU thinking power" will create new cognition work output productivity curves, which I believe will impact the world economy just as steam power did in the First Industrial Revolution.

Viewed historically, in the Third Revolution, gen AI/GPU is playing the role of steam power and will dramatically change not just radiology but likely the entire economy. In this "Cognitive Revolution," gen AI/GPU thinking power will produce prodigious amounts of radiology cognitive work output and do so using less expensive Gen AI/GPU thinking units that scale well compared to radiologist brain units that do not. Real economies of scale will only be achieved by their combination in radiology. The future of radiology will look quite different.

The revolution sequence is a repeating cycle: humans are relieved of physical labor, then additional work tasks, and now cognitive tasks. Not only are humans relieved of those tasks, but importantly those tasks are performed by different, separate production units that scale dramatically. This is happening rapidly with gen AI and current LLMs (large language models) or even small language models. When gen AI/GPU brain units perform radiology information work output of many individual radiologist brain units at a lower cost per incremental gen AI/GPU unit, true economies of scale are achieved because information work output is of lower cost. This is multiplied further if gen AI/GPU brain units produce not only radiology information work output but radiology cognitive work output at a lower incremental cost compared to a radiologist brain unit. The number of these gen AI/GPU brain units is essentially unlimited except for the energy cost required to run them.

The sequential drivers of these revolutions — steam engines, computers and now gen AI/GPUs — all have in common the ability to perform human production tasks as separate production units that can scale up dramatically compared to humans performing these tasks. We are truly on the cusp of something really new when we scale up human cognition tasks without human links. Cognition can achieve economies of scale not achievable by human brain units. It's the steam-driven machine stamping out horseshoes without the blacksmith. This Third Revolution will be accelerated when quantum computing replaces current GPUs.

Radiology has gradually leveraged the previous two industrial revolutions, but leveraging the Cognitive Revolution will be different and indeed will be much faster than the gradual pace of the previous two because this one is even more transformative. AI in its many forms will not replace the raison d'être of radiology in human health, but it brings economies of scale to every component of its value chain.[1] Even interventional radiology should prepare for the new Cognitive Revolution with the separation of cognition from production.

I was fortunate to witness firsthand the gradual effects of the First and Second Revolutions on radiology. I look forward to observing the Third Revolution's lightning-speed transformation of radiology. Fortunately, our Department is well-designed for this new speed.

[1]Enzmann DR. Radiology's Value Chain. Radiology. 2012 Apr;263(1):243-52