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Resuscitation great

G Guy Knickerbocker: A GIANT OF RESUSCITATION with a fertile mind

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G Guy Knickerbocker, pioneer in resuscitation medicine and the critical leader to recognize the value of chest compressions to save lives from cardiac arrest, died, as stated by his family, peacefully, at age 89 on June 21, 2022 (Fig. 1). Knickerbocker was the youngest and critical member of the team whose names became embedded in the mind of every American medical student for the past 50 years as the creative force for chest compression use in Cardiopulmonary Resuscitation (CPR): Jude, Kouwenhoven and Knickerbocker.

Knickerbocker was the lead person in this story not because of the most famous anecdote of discovery of the value of rhymical chest compressions, but because of his forceful recognition of the potential value of this technique to saving lives. His efforts led to the use of CPR by every medical professional and ultimately every willing and able non-professional volunteer.

James Jude, a cardiac surgeon in training, described Knickerbocker's initial observation as "A chance observation to a fertile young mind."[1] What was the background of this fertile young mind? G. Guy Knickerbocker was born on November 21, 1932 in Pine Plains, NY. He loved classical music, sang in the choir as an adult and learned multiple instruments. He played guitar his whole life. After several moves the family settled in Catonsville, MD where Knickerbocker would attend Catonsville High school for his senior year. While he was very bright, it was decided he would attend a state school and become a teacher at the State Teachers College. Unexpectedly, Knickerbocker was informed he had been chosen for a scholarship that would pay for his full tuition and textbooks at the prestigious Johns Hopkins University. This news was life changing and allowed him to shoot for the stars and study engineering. In addition, in order to be considered for a Master's program, students were required to learn two foreign languages. Knickerbocker would become proficient in French and fluent in Russian. These language skills would come to serve him well as he worked in the international resuscitation community later in life.

Knickerbocker met Dr. William B. Kouwenhoven who was the Dean of the Johns Hopkins School of Engineering and in 1954 was invited to join Kouwenhoven's laboratory for his Master's Degree research after Kouwenhoven retired from the Deanship, Alfred Blalock, the Chair of the Johns Hopkins Department of Surgery, invited him to transfer his work to the laboratory Blalock had embedded within the Johns Hopkins Hospital. The lab was on the 12th floor of what and is now known as the Blalock Building. A young cardiothoracic resident, Jim Jude, was working down the hall studying the interaction of hypothermia and cardiac arrest. He would get to know Kouwenhoven and Knickerbocker well, borrowing the defibrillator they created when his animals went into ventricular fibrillation.

Knickerbocker became part of Kouwenhoven's work to develop a portable, transthoracic defibrillator. Kouwenhoven, Knickerbocker and colleagues methodically tested numerous variables that might impact the ability to successfully defibrillate a dog who was in ventricular fibrillation (Fig. 2). Amongst other variables they studied paddle placement, size of the paddles, and different types of energy. For example, they noted by placing one of the paddles at the sternal notch and the other inferolateral to the heart, the amount of current needed to defibrillate the heart dropped significantly.[2] The team's work had succeeded to the point of creating a viable device that could defibrillate, with alternating current, through the chest and was portable. However, the definition of "portable" was far from what we would envision today. The machine weighed approximately 200 pounds but was on wheels and could be rolled to a patient's bedside. At the time of this important story, the infamous defibrillator lived at the "Heart Station", on the 5th floor of the Johns Hopkins Hospital.

A final piece of the puzzle, setting the context for Knickerbocker's important observations is related to the amount of time a heart is fib-

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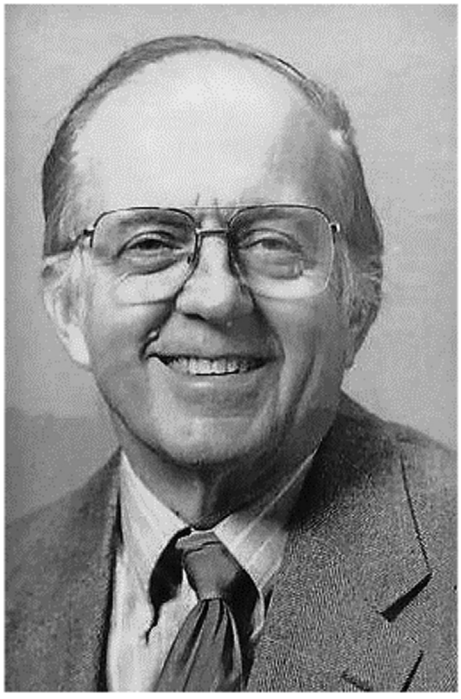

Fig. 1 – Recent photo of Guy Knickerbocker.

Fig. 2 – Guy Knickerbocker (left), William Kouwenhoven (middle) and Jim Jude (right) reviewing EKG and waveform data from closed chest cardiac massage experiment in Science Building Lab in Johns Hopkins Hospital circa 1960. The Alan Mason Chesney Medical Archives of Johns Hopkins University.

rillating when an attempt is made at defibrillation. In 1932, Hooker, Kouwenhoven and Langworthy noted if the heart remained in ventricular fibrillation longer than two minutes, the countershock would not be effective at converting the heart to sinus rhythm.[3] However, it was also noted that if epinephrine was injected and internal cardiac massage was performed, circulation could be re-established by providing a countershock after as long as eight minutes of ventricular fibrillation. A key question was how to provide circulation of blood to the heart, regardless of the location of the patient and without the specialized skill of being able to perform an emergent thoracotomy?

To relate the story once more: In 1958 Knickerbocker noticed when the large defibrillator paddles were placed on the chest of the dog to defibrillate, there was a rise in femoral artery pressure measured by a continuous recorded pressure monitor. The pressure dropped when the paddles were taken off the chest and raised again when the paddles were depressed. Knickerbocker, Kouwenhoven and Jude were all intrigued and discussed creating a plan to study. Knickerbocker was subsequently confronted by a dog that developed ventricular fibrillation that was not anticipated. The experimental defibrillator he knew was located on the 5th Floor of the Blalock building well below the 12th floor dog research laboratory. Knickerbocker started rhythmically pushing on the chest of the dog with his hands then asked his colleague to take over and "keep pushing on his chest until I get back." He ran from the lab, down 14 flights of stairs (two flights for each floor), burst onto the 5th floor and ran to the Heart Station. He grabbed the defibrillator and rolled it to the elevator and waited for the notoriously slow elevator. Knickerbocker was once asked "Did you push the elevator button over and over?" The person asking the question imagined the anxiety of waiting for the elevator, trying to command a faster response with the repeated pushes. Knickerbocker responded with his ever-calm voice, speaking from his rational engineering brain "Why would I do that?".

Knickerbocker estimates that by the time he returned to the lab and defibrillated the dog, it had been approximately 20 minutes from the onset of the ventricular fibrillation. His brain told him that they had never seen a heart be successfully defibrillated after five minutes of no circulation. His heart told him this was going to work. He pushed the paddles down on the chest, delivered the countershock and his heart leaped to see the EKG immediately change from ventricular fibrillation to sinus rhythm. The dog quickly regained a pulse and started breathing spontaneously. The next day, the dog was his usual playful self.

This was not really a unique experimental observation, as careful review of the German and Russian language literature revealed. But what was Knickerbocker's real contribution: it was a more than fifteen-year commitment to extending this observation to the world of clinical medicine and beyond. Imagine that in two years this idea of Knickerbocker was advanced by James Jude, and Kouwenhoven from a one-time accidental observation in a dog to the reporting of the first successful clinical use, outside of the operating room, in the Journal of the American Medical Association in 1961.This time lapse included the one year of exasperating time for the Journal to accept the submitted manuscript for the publication entitled: "Closed-Chest Cardiac Massage."[4] Most of the patients in this first report had cardiac arrest without ventricular fibrillation but the fifth and last patient was a direct translation of the dog experiment on a patient. The authors of this paper are Kouwenhoven, Jude and Knickerbocker.

"Case 5.—A 45-year-old man was brought to the emergency room of the hospital with excruciating substernal chest pains radiating down both arms on Jan. 6, 1960. He was conscious when admitted. While removing his clothing, preparatory to examination, he fell to the floor. His respirations ceased, and there were no heart sounds and no pulse. The house officer immediately began closed-chest cardiac massage. An electrocardiogram was taken and showed the heart to be in ventricular fibrillation. The patient began to breathe spontaneously. Ten minutes after the start of external massage artificial respiration by endotracheal tube was first begun. External heart massage and artificial respiration were continued for 20 minutes, while a closed-chest A. C. defibrillator was being brought to the

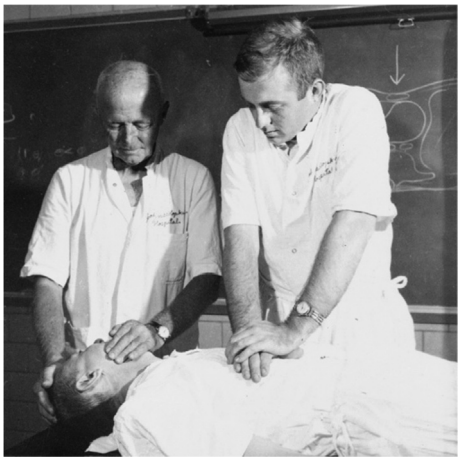

Fig. 3 – Guy Knickerbocker with hands on chest, W.B. Kouwenhoven opening airway, Jim Jude as victim – demonstrating closed chest cardiac massage - circa 1960. The Alan Mason Chesney Medical Archives of Johns Hopkins University.

emergency room. Two defibrillator shocks were given; the first temporarily arrested the fibrillation. After the second shock the heart resumed natural beats. An electrocardiographic tracing taken two hours later showed an anterior myocardial infarction. Subsequent tracings confirmed the diagnosis." "The patient had no sign of central nervous system damage, except amnesia for the period of cardiac massage plus two hours. He has followed, without incident, the usual course of treatment for myocardial infarction."[4]

Cases 2, 3, and 4 were patients who had cardiac arrest in the setting of initiation of Fluothane (Halothane) anesthesia. Halothane was approved by the FDA in 1958 as a non-flammable replacement for ether, but its proper dosing was not yet established, and it could cause profound hypotension in overdoses. In each of cases 2–4, the patient was noted to be pulseless shortly after initiation of halothane. All were promptly resuscitated with chest compressions, providing lifesaving blood flow while the excess halothane dissipated.

Knickerbocker was at the center of all efforts with his colleagues to bring this to medical and public attention and use over subsequent years (Fig. 3). They embraced the work of Peter Safer and colleagues to provide mouth to mouth ventilation. They produced a landmark display booth at the American Medical Association national meeting in 1961. For the meeting Knickerbocker created one of the first advanced life support simulators with three innovative components, creating a uniquely immersive experience. First was a compression training manikin and second was a replica of the defibrillator enabling participants to operate the device in a realistic manner. Third, Knickerbocker created a simulated electrocardiogram, variably displaying sinus rhythm or ventricular fibrillation. They were awarded the Hektoen Gold Medal for the Best Overall Display by the American Medical Association (Fig. 4). The medal was donated to Johns Hopkins by Guy Knickerbocker at the celebration of the 50th anniversary of CPR at Johns Hopkins and sits in the Chesney Archives of Johns Hopkins. Knickerbocker led many field demonstrations across the country and in Europe to ultimately gain in the U.S. a national consensus and program commitments from the Red Cross and the American Heart Association to initiate the training of the public in CPR. With this singular effort and time commitment that Knickerbocker made to establishing CPR, he was awarded his doctoral degree from Johns Hopkins University a few years later. Soon after the award of his degree he left Johns Hopkins and then worked for 30 years for ECRI (originally Emergency Care

Fig. 4 – Hektoen Medal awarded to WB Kouwenhoven, JR Jude and GG Knickerbocker for the Best Scientific Exhibit at the American Medical Association Annual Meeting in New York in 1961. The exhibit was entitled "Closed Chest Cardiac Massage and Defibrillation" and was one of the first advanced life support simulators of chest compressions and hands on defibrillation. Photo from personal collection of Elizabeth A. Hunt.

Research Institute) a medical device assessment company as Chief Scientist and Expert Witness.

In 1984, Arnold Sladen opined that the 1960 JAMA publication "may have resulted in saving more lives than any other medical manuscript in the past century."[5] There is a certainty that Guy Knickerbocker knew well the landmark contributions he made to human health and survival from cardiac arrest.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

1. J.R. Jude, Personal reminiscences of the origin and history of cardiopulmonary resuscitation (CPR). *Am J Cardiol.*, **92** (8), 2003, 956–963.
2. Acosta P, Varon J, Sternbach GL, Baskett P. Resuscitation great. Kouwenhoven, Jude and Knickerbocker: The introduction of defibrillation and external chest compressions into modern resuscitation. Resuscitation 2005;64(2):139–43.
3. Hooker DR, Kouwenhoven WB, Langworthy O. The effect of alternating electric currents on the heart. Am J Physiol 1933;103:444–54.
4. Kouwenhoven WB, Jude JR, Knickerbocker GG. Closed-Chest Cardiac Massage. JAMA 1960;173(10):1064–7.
5. Sladen A. Landmark perspective: Closed-chest massage, Kouwenhoven, Jude, Knickerbocker. JAMA 1984;251(23):3137–40.