# 1 Simulation in Obstetric: From the History to the Modern Applications

Reuven Achiron, Laura Adamo, and Tal Weissbach

## 1.1 Introduction

The term simulation derived from the Latin word *simulo*, meaning to pretend or imitate.

According to common dictionaries, the definition of the word "simulation" is "a situation in which a particular set of conditions is created artificially in order to study or experience something that could exist in reality" [1].

Simulation is integrated in many aspects of our lives: entertainment, military, financial to cite some, and of course medicine.

Simulation in the medical field has advantages that are now widely recognized. Simulation can teach, test, and prepare for important clinical scenarios. Besides facilitating the acquisition of new skills and the maintaining of previously acquired skills, simulation assists in gaining experience in the management of emergencies and life-threatening conditions without inflicting harm to the patient.

The Society for Simulation in Healthcare defined simulation as "an educational technique that replaces or amplifies real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner" [2].

Simulation in obstetrics has developed from a necessity to improve medical student's education to an integral working tool for every level of expertise, recognizing the importance of maintaining high standard level of care, as an individual clinician or a team of caregivers.

## 1.2 History of Obstetrical Simulation

A PubMed search of the words "simulation" and "obstetrics" led to more than 5000 articles, most of which have been published within the last 10 years.

Despite recent interest, obstetric simulators have been already documented since the seventeenth century and, considering simulation in general medical education, its roots are dated millennia ago [3].

In 1027, the Chinese physician Wang Wei-Yi (987–1067), standardized the teaching of acupuncture with two life-size statues made of bronze, that had more than 300 holes to demonstrate to the students the locations of acupuncture points [4] (Fig. 1.1).

In Europe, following the end of the Middle Ages, a new era of Renaissance emerged with a strong desire of knowledge and innovation.

*De humani corporis fabrica libri septum* written by Andrea Vesalio (1514–1564) in 1543, revolutionized the interest of anatomy studies [5] (Fig. 1.2) and half a century later, Ludovico Cardi (1559–1613) produced the first wax anatomical model.

These carved figures became a common teaching tool throughout Europe and typically presented either male or female organs. The female version was often featured as pregnant including a fetus attached to the mother by a red silk string as an umbilical cord [6].

Giovanni Antonio Galli (1585–1652), a surgeon based in Bologna, recognized the importance of increasing midwive's education since often they were lacking essential knowledge and technical skills [3] (Fig. 1.3).

He designed one of the first birth simulators which included a pelvis containing a glass uterus with a flexible fetus.

Galli's simulator and other obstetric teaching models can still be admired at Musei di Palazzo Poggi in Bologna.

R. Achiron · T. Weissbach
Department of Obstetrics and Gynecology, Prenatal Diagnosis Unit, Chaim Sheba Medical Center, Tel Hashomer, Israel

Sakler School of medicine, Tel Aviv University, Tel Aviv, Israel

L. Adamo (✉)
Department of Obstetrics and Gynecology, IRCCS Fondazione Policlinico San Matteo, University of Pavia, Pavia, Italy


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**Fig. 1.1** Acupuncture statue used by Wang Wei-Yi in China during the eleventh century

The role of obstetric simulation became increasingly more popular throughout European countries and various models were created for teaching and developing skills.

By the middle of seventeenth century, Angelique Marguerite Le Boursier du Coudray (1712–1794) was summoned by King Louis XV to educate midwives to decrease intrapartum mortality in rural France.

She developed innovative female pelvis simulators, with interchangeable cervices to assess different cervical dilations and with different-sized fetuses. These high-fidelity mannequins were also able to emulate rupture of membranes and hemorrhage.

Madame Du Coudray incorporated the practice of simulation with traditional frontal lectures, developing an instructional course of 40 lessons addressing management of labor and its complications [7] (Fig. 1.4).

Contemporaries to madame Du Coudray, two surgeons, father and son, the Gregoires made their own obstetric simu-


**Fig. 1.2** *De humani corporis fabrica libri septum* consecrated Andrea Vesalio as the father of modern anatomy

lator known as the "phantom" using a human cadaver pelvis, a woven leather uterus, and deceased neonates as fetuses [8].

One of the most famous Gregoire pupil was the Scottish William Smellie (1697–1763), known for his studies on pelvis deformities and for vaginal assessment of the obstetric conjugate [9]. Once back in the United Kingdom, Smellie decided to design an improved version of the Gregoire phantom. In order to avoid using cadavers for training, his phantom was composed of human bones covered in leather, a fetus made of wood and rubber with articulating limbs and a placenta [3, 10] (Fig. 1.5).

In 1831, there was a big improvement in mannequins technology, when Doctor Gustave Ozenne (1822–1871) presented to the French Royal Academy of Medicine a very sophisticated whole-body patient simulator that he worked on for 6 years.

**Fig. 1.3** In 1757, Giovanni Antonio Galli professor of obstetrics in Bologna, created the Galli's "machine" as a teaching tool for midwives and medical students

The uterus was made of longitudinal and radial fibers to simulate uterine contractions, with the possibility of changing the strength, rate, and rhythm. There was an amniotic sac and the fetus skull had fontanelles, a moveable lower jaw, and a rump to allow students to recognize different fetal presentations and practice uncomplicated deliveries. They could even protect the perineum from tearing.

Ozenne reported the benefits of teaching the management of a physiologic labor, but also the opportunity to recreate obstructed labors and possible interventions [11].


**Fig. 1.4** In the middle of seventeenth century, Angelique Marguerite Le Boursier du Coudray developed high-fidelity mannequins that were able to emulate different cervical dilatations, rupture of membranes, and hemorrhage

Few years later, following Ozenne's footsteps, Pierre Budin (1846–1906) and Adolphe Pinard (1844–1934) developed an internal and external digital palpation simulator, enabling to determine the fetal presentation and position as well as performing forceps application (Figs. 1.6 and 1.7).

Obstetric pelvimetry and the study of birth mechanisms was a push forward for European obstetric school's simulations (Fig. 1.8). The understanding of the pathological pelvis led to research and simulation of the descent of the fetal head within the birth canal such as Selheim's theory of asynclitism (Fig. 1.9).

Throughout the 1800s, simulation was widely used all around Europe with various model types, some of them even included detailed instruction manuals, like the one designed by Professor Schultze at the University Women's Hospital in Jena, Germany. It had interchangeable pelvic floors and sacral promontories for an improved pelvic anatomy simulation for teaching clinical pelvimetry. Moreover, Shultes Medacta, founded by Prof. Shultze, began large-scale phantom manufacturing from 1890, making it the oldest existing supplier of medical simulators [3].

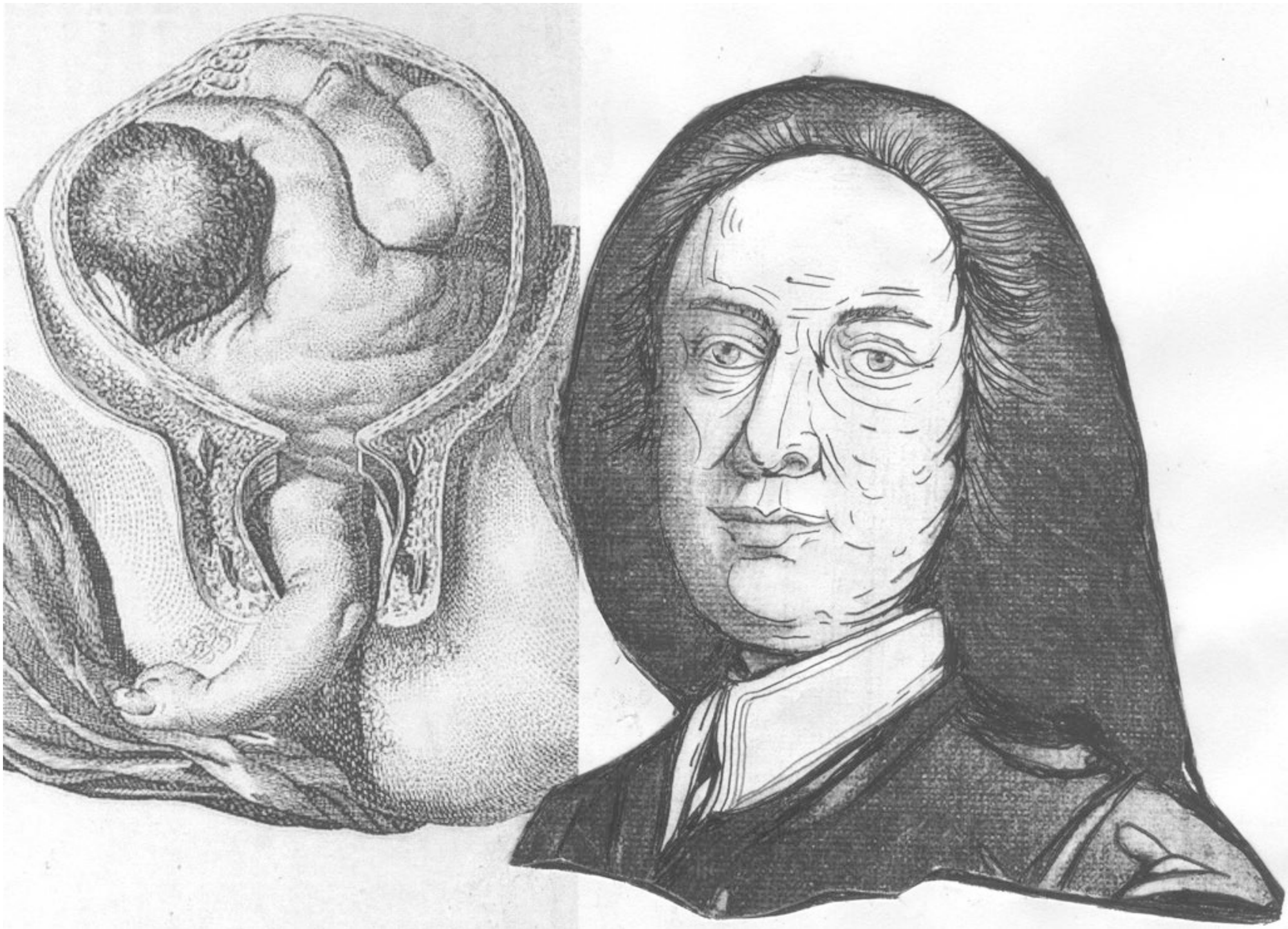

**Fig. 1.5** The Scottish William Smellie designed an improved version of the Gregoire phantom, using human bones covered in leather, a fetus made of wood and rubber with articulating limbs and a placenta

Overseas, in the United States, simulation began to be widely used in medical schools around the country to compensate for the lack of births in hospitals [12]. In 1910, Flexner published a report named Medical Education in the United States and Canada, which led to a reform in American medical education [13].

In particular, he perceived the mannequin as a useful tool for teaching and preparing students for clinical practice, admonishing some schools for making poor use of them.

However, despite the great advancements made in the field of obstetrics over the previous 50 years, simulators were still designed based on seventeenth century models (Figs. 1.10 and 1.11). Additionally, the increasing number of hospital deliveries led to a higher exposure to clinical practice, which consequently made the role of the simulation wane.

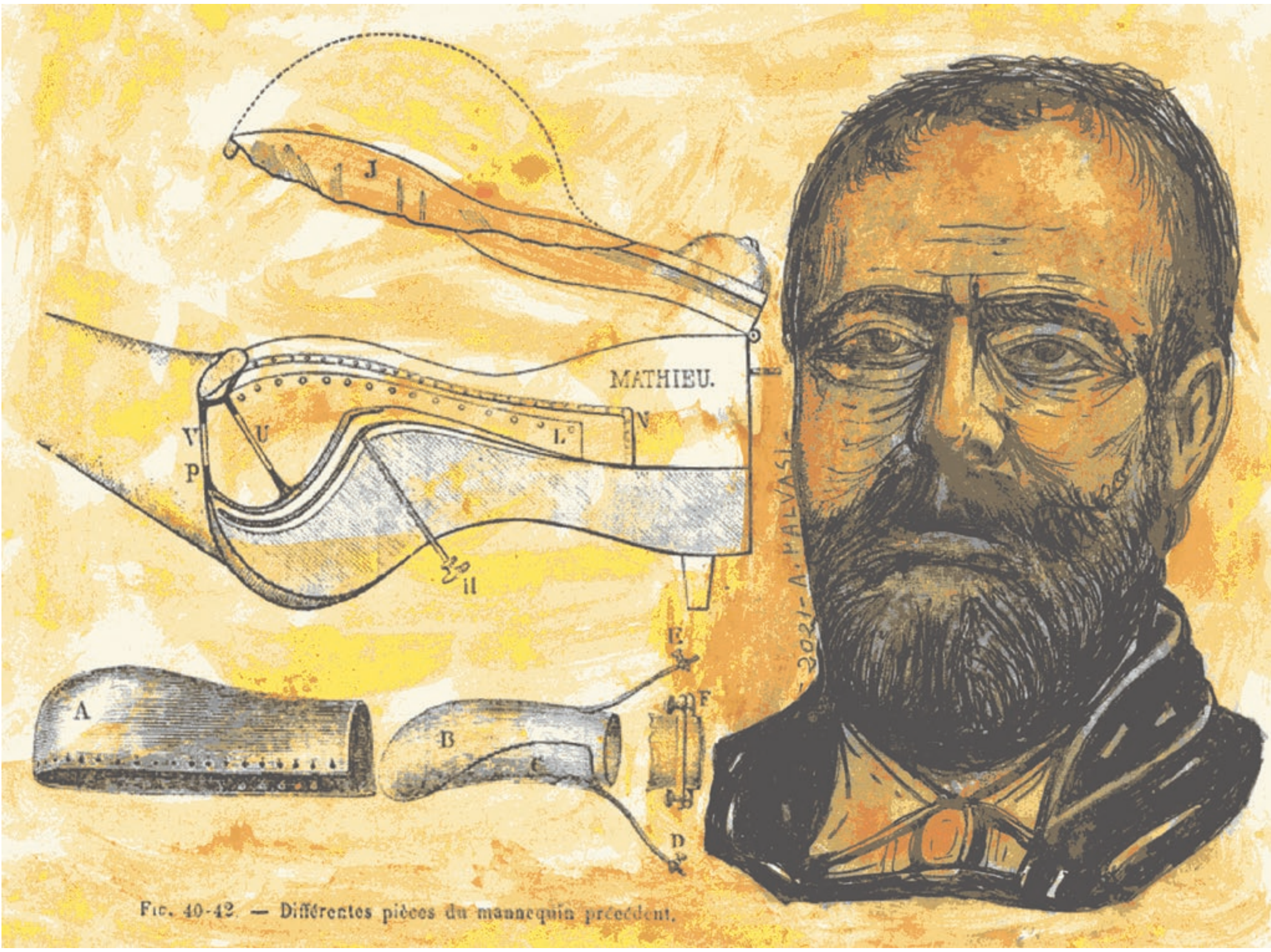


**Fig. 1.6** A draft of Budin–Pinard mannequin made by Maison Matieu and sons in Paris


**Fig. 1.7** Mannequin used to teach the operative childbirth with forceps during the nineteenth century

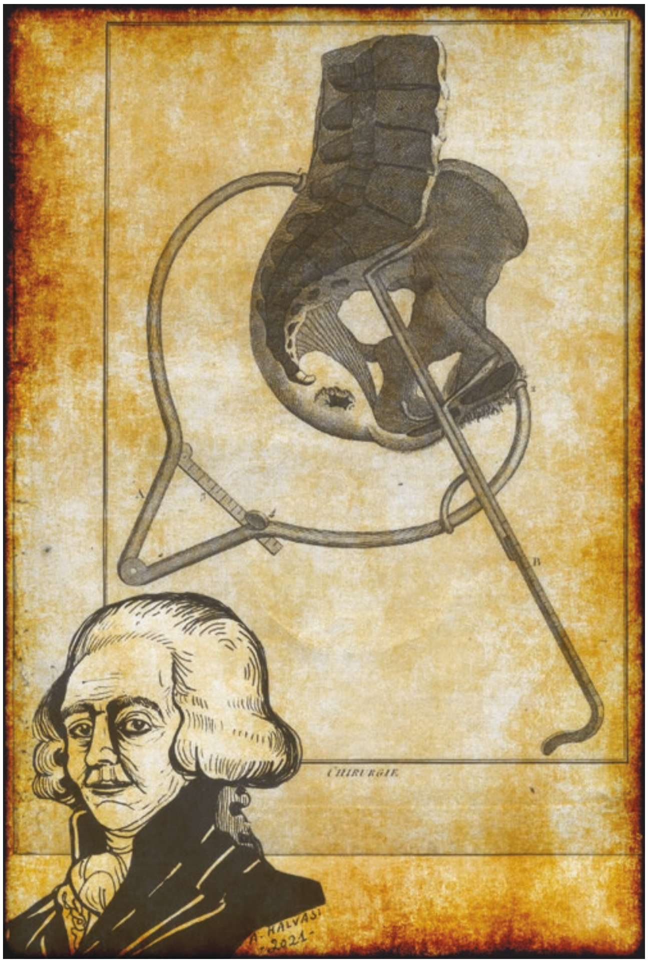


**Fig. 1.8** Jean-Louis Baudelocque, a pioneer of pelvimetry

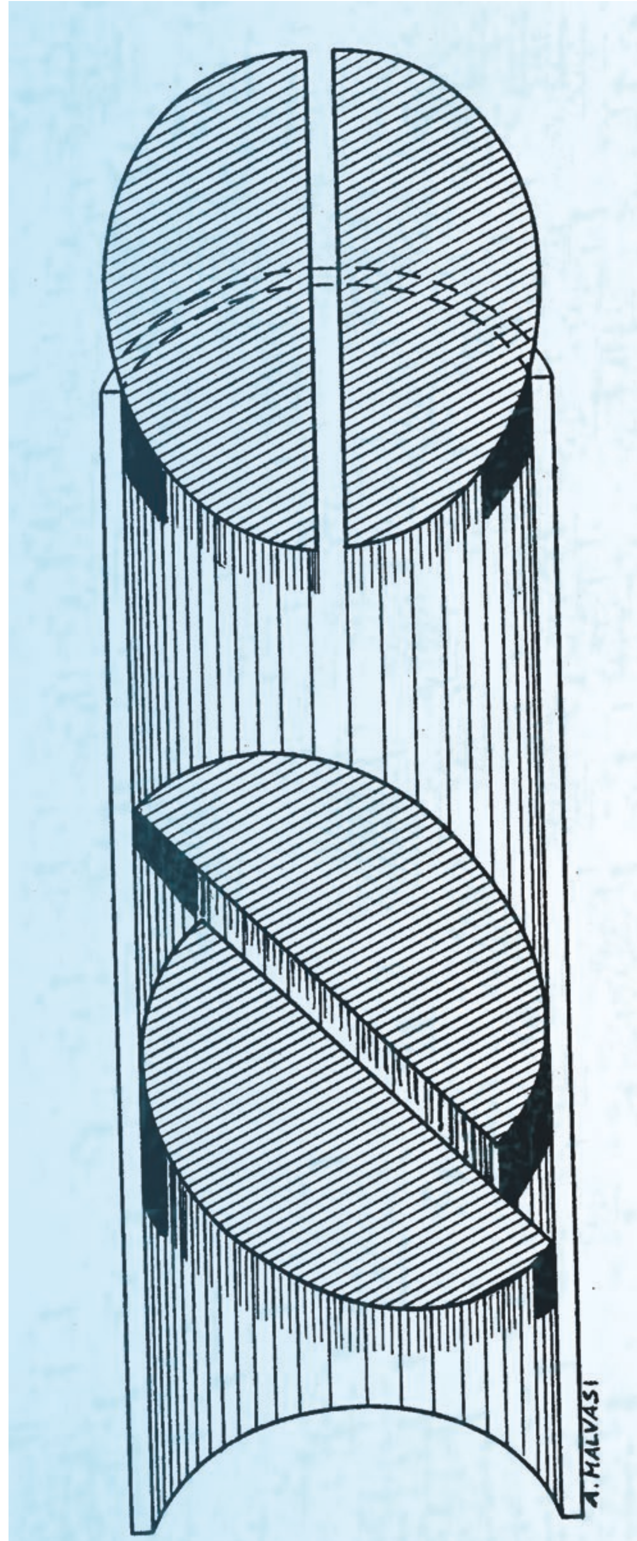


**Fig. 1.9** Graphic simulation of the descent of the fetal head in anterior asynclitism according to Selheim

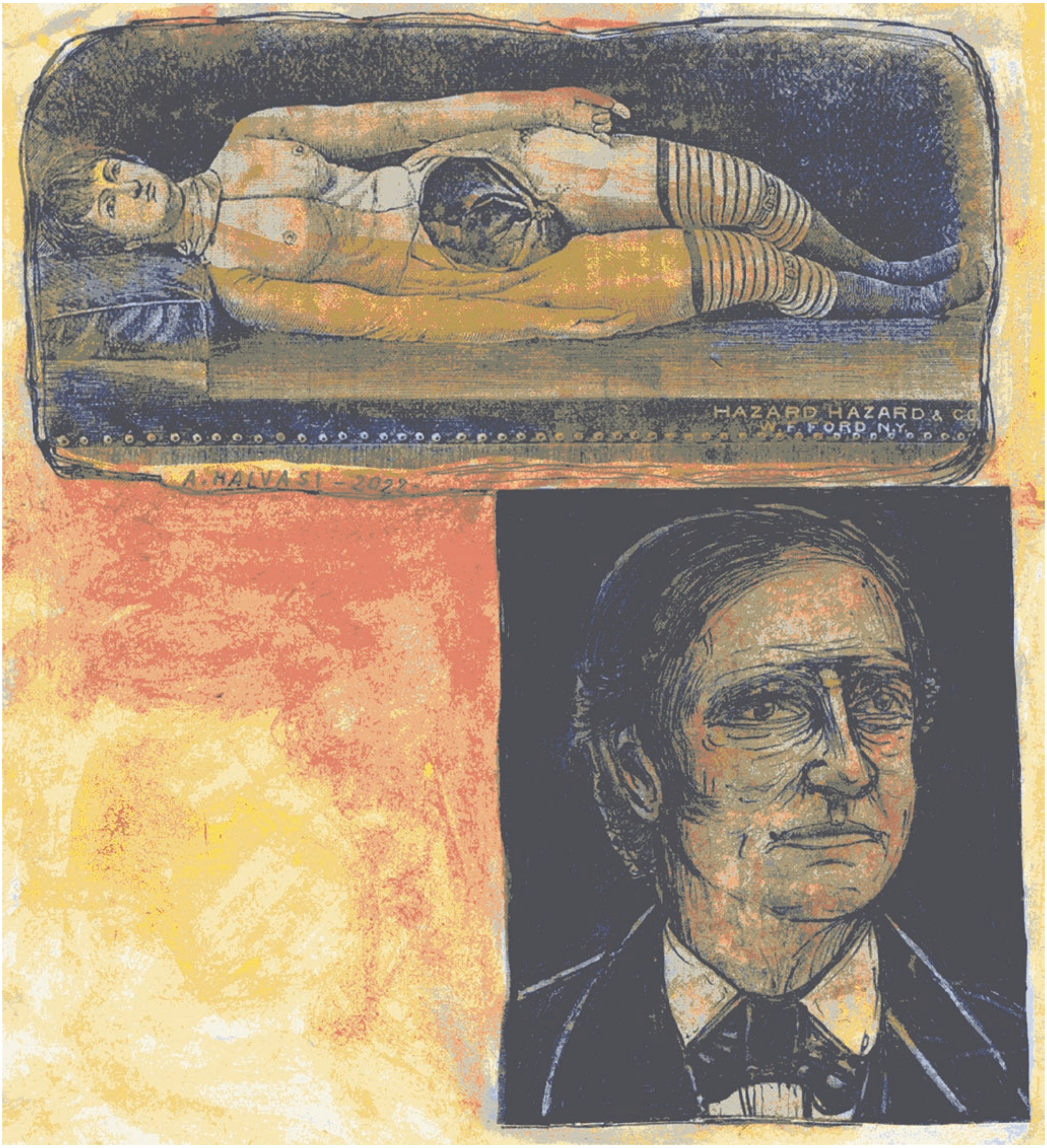


**Fig. 1.10** Professor Theophilus Parvin's mannequin, anterior view

**Fig. 1.11** Professor Theophilus Parvin's mannequin, posterior and lateral view

## 1.3 The Twentieth Century Became a "Dark Age" for Simulation

Only towards the end of the twentieth century, contemporary changes in technology and the heightened concern for patient safety, renewed the interest in simulation once again.

In 1968, the first modern high-fidelity medical mannequin, named Harvey, was designed. It was able to simulate vital signs and heart sounds, thanks to computerized technology [14].

Harvey was an innovation that paved the road for the development of the modern-day obstetric simulators.

Simulators were progressively becoming more realistic. They enabled training practitioners to visualize the descent of the fetus through the birth canal, to place forceps, to practice shoulder dystocia maneuvers.

Simulation was focused on improving specific and confined practical skills. What was still lacking was the ability to recreate obstetric emergency scenarios in order to assess and improve teamwork efficacy.

An airplane crash provided significant insights on the importance of team training. Investigators identified a lack of communication between the pilot and crew, which led to a wrong management of a malfunctioning light and distracted the pilot from identifying a lack of fuel.

The aviation industry was already using flight simulators, however, there was still a need of creating programs aimed to increase collaboration between pilots and crew in identifying problems. It was clear that every member of the team was essential and has an individual responsibility which, when synchronized, could contribute to optimal management of critical situations [15].

In 2001, the first international meeting on medical simulation met as part of an anesthesiology technology conference.

Three years later, the Society for Simulation in Healthcare (SSH) was founded [16].

In addition to the SSH, individual medical specialties created specific simulation working groups.

Likewise, principal bodies in the field of Obstetrics and Gynecology began to acknowledge the importance of simulation. The American College of Obstetricians and Gynecologists (ACOG) and the Society for Maternal-Fetal Medicine (SMFM) began to offer hands-on simulation courses during their annual meetings.

The ACOG Simulations Consortium was created in 2009 with the aim of "establishing [simulation] as a pillar in education for women's health through collaboration, advocacy, research, and the development and implementation of multidisciplinary simulation-based educational resources and opportunities for Obstetrics and Gynecology" [17].

## 1.4 The Role of Obstetrical Simulation Today

Nowadays simulations can take many forms.

Simulation can be a towel folded over a chair to represent a perineal laceration (low fidelity) and can be a breathing and bleeding robot in an immersion data cave (high fidelity). Simulation can be a role play with live actors, can take place in virtual reality, or it can be a tutorial on a desktop computer [18].

To a degree, simulators should be realistic in order to create real-life situations and working conditions. However, overly sophisticated technology could have an opposite effect, by over guiding the training practitioner and creating a nonrealistic situation.

Macedonia et al. pointed out this concept and created the ARRON rule (As Reasonably Realistic as Objectively Needed).

Several studies demonstrated the efficacy of the ARRON rule showing, for example, that simulation of shoulder dystocia can be managed on a low-fidelity mannequin [19] and that medical students do not need high-fidelity simulators to understand vaginal birth [20].

There are countless advantages to simulation-based training such as an organized learning environment, the ability to control clinical parameters, providing immediate feedback, and an objective method for assessing performance.

Through simulation, skills can be practiced until mastered, without inflicting harm to patients. Simulation helps to acquire and refine both cognitive and technical skills necessary to perform complex patient care activities. It can be used to train complex decision making, to practice rare or acute clinical emergencies, and to learn and practice skilled maneuvers [21, 22].

Several studies have demonstrated the expanding roles of simulation in undergraduate medical education in the field of obstetrics and gynecology.

Compared to traditional lectures, simulation programs in pelvic examination, cervical dilatation, and vaginal delivery, have been shown to be superior in terms of confidence, knowledge, skills, workplace behaviors, and translation to patient care [23–29].

Simulation can be beneficial for mastering any newly learnt procedure during residency. While senior clinicians might have accumulated experience and knowledge in obstetrical emergencies over time, residents are inexperienced and rely on standard medical education. Therefore, it is not surprising that interventions such as simulation and drills have shown a positive impact on clinical management and skill acquisition among obstetrics residents.

Commonly reported topics in residency include operative vaginal delivery, breech delivery, twin delivery, cord pro-

**Fig. 1.12** Simulation of cord prolapse on mannequin in the School of Obstetrics and Gynecology of the University of Bari, Italy

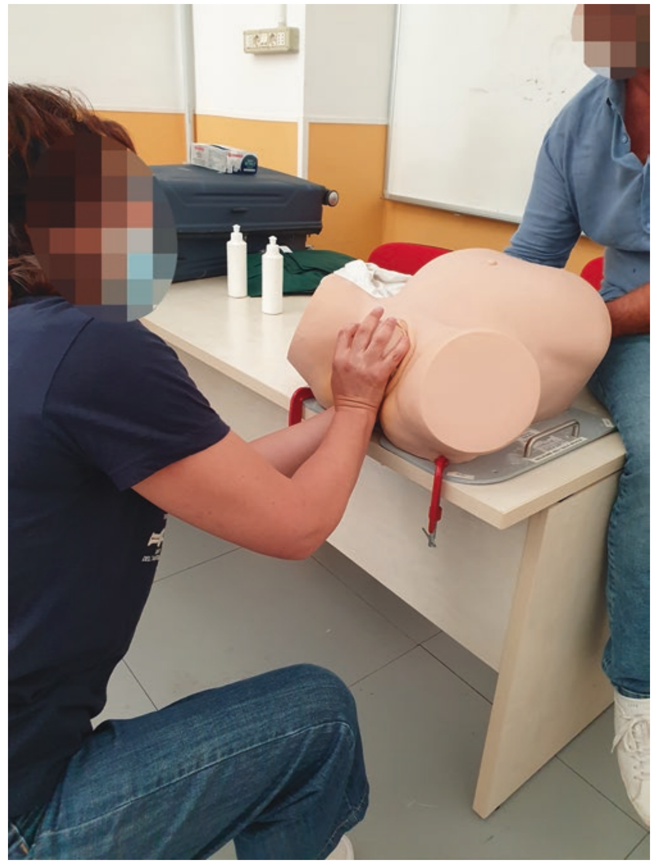

**Fig. 1.13** Shoulder dystocia simulation conducted by the School of Obstetrics and Gynecology of the University of Bari, Italy

lapse (Fig. 1.12) management of shoulder dystocia (Figs. 1.13 and 1.14), third- and fourth-degree laceration repair, management of eclampsia, and hemorrhage.

For example, the decline in the number of breech deliveries has gravely affected the ability of contemporary residents to manage this type of event, leading to the development of simulation training in these and other rare conditions. Deering et al. [30] have reported an improvement in residents' management of a vaginal breech delivery after simulation. Easter et al. [31] described that after simulating a breech extraction on a nonvertex second twin, residents personal comfort improved from 5.5% to 66.7%.

One of the most common procedures required in obstetrics is an operative delivery. A systematic review of eight studies suggested that operative vaginal delivery simulation is a promising tool to increase trainee skills, knowledge, and confidence, while also improving maternal and neonatal outcomes [32].

Similar observations were found when comparing the performance of residents after simulating the management of shoulder dystocia and eclampsia to those receiving standard didactic education [33, 34].

**Fig. 1.14** Rubin maneuver to solve Shoulder dystocia on a mannequin

Simulation has a crucial role in emergency scenarios that require a quick yet appropriate response from medical providers.

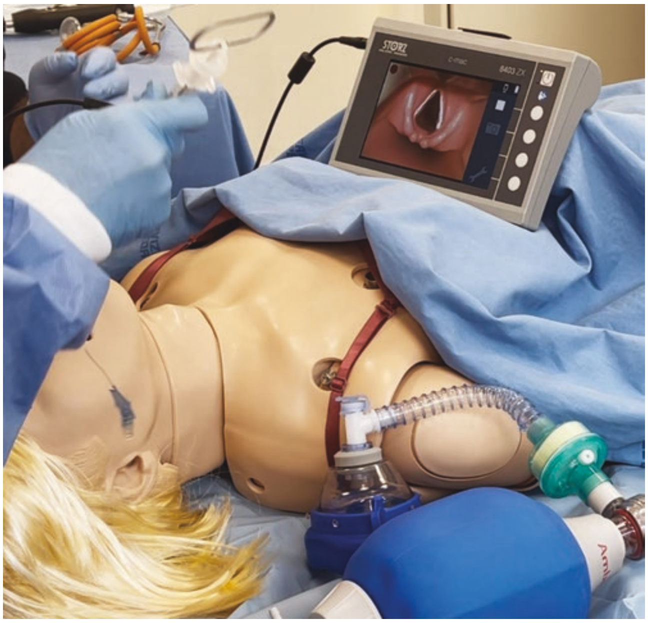


**Fig. 1.15** Difficult airway management simulation in obstetrics emergencies

Often, emergency situations require a team of caregivers working in a coordinated manner.

Anesthesiologists, as part of the obstetric team, should be trained in difficult airway management, for example, by use of videolaryngoscopy with a special curved d blade (Fig. 1.15).

Commonly, acquiring hands-on clinical experience through real-life emergency cases is limited. First, life-threatening situations always require intervention by the most skilled caregiver nearby, limiting less experienced co-workers to take full charge of the situation. Second, rare conditions that require special skills are less likely to be confronted in reality [35].

Simulating emergency scenarios has shown to improve efficiency, response time, appropriate order of actions, teamwork skills, and reduction of errors.

There are numerous perilous conditions and procedures in obstetrics that impact the health of both the parturient and neonate, thus require prompt action. These include operative delivery, emergency cesarean section, shoulder dystocia, cord prolapse, postpartum hemorrhage, eclampsia, and maternal cardiac arrest.

A review by Deering and Rowland has shown the various types of models used for different emergency situations and the benefit gained [36]. For example, practicing cesarean section on mannequins has led to a better understanding of the different steps and, thereby, to an increased sense of confidence by the performing clinician [37].

Likewise, eclampsia management has been shown to improve after simulation [34].

In fact, Ellis et al. have demonstrated that simulation training of eclampsia drills has enhanced team performance, increased the rate of task completion, and shortened the time to magnesium sulfate administration [38].

Shoulder dystocia and perimortem cesarean delivery are additional examples of emergencies that have benefited from the use of simulation [39].

The advantages of simulation training in improving clinical skills are unquestionable, but does it improve the clinical outcomes?

Most of the studies presented so far have focused on education, describing the learning curve of performance measured on the corresponding simulator.

Even if large randomized studies are lacking, there is evidence of clinical outcome.

Over a 12-year period, Crofts et al. [40] have demonstrated how the implementation of simulation training for shoulder dystocia management has led to a reduction in newborn brachial plexus injuries.

Gossett et al. [41] reported that a program focusing on forceps-assisted vaginal delivery has led to a 26% reduction in severe perineal lacerations while increasing the proper use of forceps in labor room.

Umbilical cord prolapse is another obstetric emergency that has exhibited an improvement in management as a result of simulation. After simulation drills, a shorter time to delivery and higher likelihood of cord compression alleviation maneuvers were demonstrated [42].

A half-day simulation-based training program in Tanzania has proven a 38% reduction in postpartum hemorrhages. The hemorrhage rate drop was associated with a better performance of basic delivery skills and appropriate use of oxytocin [43].

A Cochrane Library review in developing countries demonstrated how a standardized neonatal resuscitation training program resulted in the reduction of early neonatal and 28-day mortality, compared with basic newborn care [44].

A study conducted by the Department of Defense showed how teamwork training was able to reduce the time to incision for an immediate cesarean delivery from 33 to 21 min [45]. There are is a wealth of evidence to show the clear contribution of simulation to clinical management.

## 1.5 Future Perspectives

Simulation helps to overcome the limitations of current formal medical education.

During the upcoming years, we expect to see a wider use of simulation in the assessment of residency programs and board examinations.

Standardizing simulation programs will allow a more homogeneous acquisition of clinical skills and emergency scenario management.

Ennen et al. [46] have based five keys components for establishing an effective simulation program:

1. Identifying the target trainee
2. Recognizing the skills required to be tested
3. Determining the appropriate frequency of simulations
4. Determining the location and required equipment (ARRON rule)
5. Debriefing and analysis of the performance

Some societies have already designed programs that incorporate simulation, however, most medical schools and hospitals do not regularly use it. The Royal College of Obstetricians and Gynecologists developed a specific birth simulation training course, named ROBuST, which emphasizes operative vaginal delivery including manual rotation and vacuum- or forceps-assisted delivery [47].

The Society for Maternal-Fetal Medicine supported John Hopkins Hospital in developing a video library of critical care scenarios. These video scenarios include pulmonary embolism, maternal cardiac arrest, hypertensive emergencies, eclampsia, severe sepsis with shock, pulmonary edema with acute respiratory distress syndrome, hemodynamic monitoring and mechanical ventilation through the ARDS net protocol, myocardial infarction, diabetic ketoacidosis, amniotic fluid embolism, Advanced Cardiac Life Support in pregnancy, massive hemorrhage and perimortem cesarean delivery [48].

While standardizing skills among physicians, each unit should use simulation to enhance their experience and efficacy.

Identifying preexisting or potential errors of team emergency management is essential for reducing malpractice. For example, Maslovitz et al. reported how, during a postpartum hemorrhage simulation, an underestimation of blood loss led to a tardive prostaglandin treatment for uterine atony, which, in turn, has delayed patient transfer to the operating room and administration of blood products [35].

Use of simulation is the perfect setting to introduce, reinforce, and practice effective team performance.

Currently, there are no standardized obstetric simulation courses that have been associated with improvement of clinical outcomes. Large multicenter trials are necessary to determine best practice and understand where simulation resources should be implemented.

## 1.6 Conclusions

Simulation is not a substitute for clinical experience, but nonetheless is an essential additive to training and patient safety improvement [48].

Acquiring new skills and managing rare complications or emergency scenarios are subjected to a learning curve, which varies among individuals. Simulation cannot alter the innate learning potential; however, it can improve the learning process by exposing the individual to an optimal amount of practice.

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