Preventing litigation with a predictive model of COVID-19 ICUs occupancy

Chiara Gallese
School of Industrial Engineering
LIUC—Carlo Cattaneo University
Castellanza (VA), Italy

Elena Falletti
School of Law
LIUC—Carlo Cattaneo University
Castellanza (VA), Italy

Marco S. Nobile
Industrial Engineering & Innovation Sciences
Eindhoven University of Technology
Eindhoven, The Netherlands
Bioinformatics, Biostatistics and Bioimaging Centre—B4
University of Milano-Bicocca
Milano, Italy

Lucrezia Ferrario
Centre for Health Economics, Social and Healthcare Management
LIUC—Carlo Cattaneo University
Castellanza (VA), Italy

Fabrizio Schettini
Centre for Health Economics, Social and Healthcare Management
LIUC—Carlo Cattaneo University
Castellanza (VA), Italy

Emanuela Foglia
Centre for Health Economics, Social and Healthcare Management
LIUC—Carlo Cattaneo University
Castellanza (VA), Italy
efoglia@liuc.it

2020 IEEE International Conference on Big Data (Big Data) | 978-1-7281-6251-5/20/$31.00 ©2020 IEEE | DOI: 10.1109/BigData50022.2020.9378295

***Abstract*—The COVID-19 pandemic has generated an overall slowdown in hospital activities that might lead to delays in healthcare interventions, and the scarcity of resources can raise concerns about ventilators allocation criteria. These circumstances could lead to lawsuits against hospitals and healthcare professionals: together with Regions and States, they may be vulnerable to legal actions, due to the breach of right to health, to physical integrity and right to life, to the manifestation of the informed consent in the medical field or on the basis of contractual or Aquilian obligations. In this context, predicting the litigation rate could be useful to assess the economic impact of a dispute at a local and national level, so that hospital managers and public institutions can perform multi-dimensional and cost/benefit evaluations to decide whether to invest resources to increase critical care surge capacity. In this work we present CLIP (COVID-19 LItigation Prediction), a modeling approach supported by swarm intelligence designed to forecast the occupancy of intensive care units using COVID-19 time-series. CLIP fits a logistic model of COVID-19 patients admission in order to estimate the future number of patients, and then exploits a probabilistic model to predict the number of occupied intensive care beds, whose parameters are calibrated by means of Fuzzy Self-Tuning Particle Swarm Optimization. We assume that each individual rejected from an intensive care unit due to the lack of resources should be considered a potential plaintiff. The development and the availability of such a predictive model, that could further be used within other clinical conditions and important diseases, could help policy-makers in taking decisions under conditions of uncertainty.**

***Index Terms*—COVID-19, modeling, computational intelligence, litigation.**

I. Introduction

The world is facing disruptive changes, triggered by global challenges such as climate warming, migrations, financial crises, radical technological leaps, and waves of epidemics. The COVID-19 pandemic has created unprecedented disruption for the global health and development community, with important impact, not only from a healthcare perspective, but also from a social, legal and economic point of view.

The war against the COVID-19 pandemic has changed the perception of our lives, but even more has shed a brilliant light on the relevance and potential impact of the healthcare sector within country systems processes and mechanisms. Governments worldwide are working to establish countermeasures to stem possible devastating effects on global economy. Healthcare agencies and organizations try to coordinate information flows, issues directives and guidelines [1], to do their best for the mitigation of the COVID-19 impact, in a scenario of total uncertainty.

Focusing on hospitals, on the one hand, healthcare organizations worldwide are fighting to provide appropriate services to patients and are requiring substantial resources to continuously improve their delivery processes and outcomes [2], by revisiting their internal organizations, processes and procedures. On the other hand, healthcare organisations are facing significant pressures to implement effective and efficient management tools and frameworks, since the current decrease of budgets generates serious hurdles on their daily operations [3].

The Hospital Crisis Board have remodeled the entire healthcare distribution, providing a more efficient discharge processing of patients, thus freeing-up as many beds as possible in the wards [4], in particular those characterized by medium and high complexity of care devoted to patients with acute and severe respiratory syndromes. Within the epidemic peak and also nowadays with the arrival of the second COVID-19 wave, the virus is overloading hospitals, with the saturation of hospital beds, the increasingly demand for medical devices and equipment (from complex equipment like ventilators or extra-corporeal membrane oxygenation devices to hospital staples like saline drip bags), as well as the lack of trained healthcare professionals. The simultaneous presence of all the above factors makes the situation difficult to manage, mandating an adequate assessment. In particular, as the healthcare system becomes saturated with cases, it will become increasingly difficult to detect, track, and contain new transmission chains.

In this view, the management of both clinical and organizational issues related to COVID-19 has led all levels to operate in a context of radical uncertainty, highlighting the importance of taking decisions by relying on valid, shared, real-time, and understandable data, emphasizing the relevance of real world information [5], and, at the same time, the urgent priority to handle and manage these information seriously [6], [7].

In this virtuous cycle, the Intensive Care Unit (ICU) associations of most countries have published new guidelines to: *(i)* help healthcare professionals to face difficult choices regarding the clinical management of COVID-19 patients and *(ii)* explicitly state the allocation criteria for healthcare resources under a condition of extraordinary scarcity. Some notable examples are: the Italian SIARTI (Società Italiana di Anestesia Analgesia Rianimazione e Terapia Intensiva), who published its "Clinical ethics recommendations for the allocation of intensive care treatments, in exceptional, resource-limited circumstances" in March 2020 (SIARTI, 2020); the NIH (National Institutes of Health) "Coronavirus Disease 2019 (COVID-19) Treatment Guidelines" in the US [8]; the multiple guidelines of the NHS (National Health Service) in the UK [9]; the guidelines drafted by the SGI (Swiss Society for Intensive Care Medicine) [10]; and the Dutch "Triage thuisbehandeling versus verwijzen naar het ziekenhuis bij oudere patiënt met (verdenking op) COVID-19" [11]. These documents presented clinical ethical recommendations for the admission to ICUs, under the exceptional circumstances of an imbalance between needs of a population and availability of resources. Hospitals have been preparing to deal with a high number of patients, but also with the possibility to make difficult decisions concerning the triage, foreseeing a new wave of contagions, or even a new pandemic in the future.

The prompt availability of predictive and forecasting models, able to represent the factors influencing decisions, would represent a competitive tool to ensure the sustainability of medical care, within both National Healthcare Service-based and insurance-based countries. In fact, these models could be used to depict patient flows and care delivery processes, emulate processes and their dynamics in stochastic environment, evaluate the efficiency of current practices, carry out what-if analyses to predict the impact of staffing, resources, and operational changes on the hospital's performance [12]–[15].

In this work we present CLIP (COVID-19 LItigation Prediction), a modeling approach supported by swarm intelligence designed to forecast the occupancy of ICU beds using COVID-19 time-series. CLIP fits a logistic model of COVID-19 patients admission in order to estimate the future number of patients, and then uses a probabilistic model fit with Fuzzy Self-Tuning Particle Swarm Optimization (FST-PSO) to predict the number of occupied ICU beds. As a proof of principle, we show an example of CLIP prediction using the data from public Dutch COVID-19 databases.

The paper is structured as follows. In Section II provide a summary of the main legal implications of ICU saturation due to the COVID-19 outbreak. The CLIP methodology is described in Section III. We conclude the paper with a discussion about future developments in Section IV.

II. Legal issues

In the last decades, the lawsuits against hospitals and clinicians have greatly increased [16], even in countries where the medical malpractice litigation rate is traditionally low, such as The Netherlands [17], [18].

According to a Chinese study, the number of claims is positively and significantly dependent on both the size of the hospitals and the complexity of the medical operations [19]. Also, there are wide differences across specialties, both in rates of paid claims and in characteristics of the alleged injuries [20]. Although the rising of malpractice claims lead to a precautionary behaviour in medical professionals and even to the so called "defensive medicine" phenomenon, causing a greater healthcare expenditure [21], research shows that malpractice outcomes bear a good correlation with the quality of care as judged by other physicians [22] and that the litigation rate could be a potential indicator of healthcare quality [23]. In addition, it has been found that a high use of resources by physicians is associated with a reduced risk of malpractice claims [22].

This scenario could only be further complicated by the COVID-19 pandemic, in a situation characterized by a paucity of resources, thus limiting the number of patients that could be promptly and adequately taken in charge. This situation does not exclusively concern COVID-19 patients, but all those patients requiring clinical procedures, medical examination or hospital therapies (i.e., administration of iv. drugs or dialysis).

As previously mentioned in the Introduction section, the exponential increase in COVID-19-positive patients and the dramatically increasing need for ICU beds has led some countries to reallocate ICU resources (e.g., in Italy, Lombardy Region resolution no. XI/2906): as a result, new measures have been put in place, such as elective surgery being cancelled, and the beds previously dedicated to cardiac, neurosurgery and partially coronary care units being reassigned to COVID-19-patients [24].

It is easily understandable that the pandemic has generated an overall slowdown in hospital activities that could lead, over the time, to a continuous delay of healthcare interventions, as well as to a worsening of non-COVID outcomes and disease outbreaks [25], not to mention the discrimination concerns raised by the ventilators allocation criteria [26]. This could obviously generate an impact on lawsuits against hospitals and healthcare professionals [27]: together with Regions and States, they may be vulnerable to legal action, and the lack of an adequate legal protection may prevent an effective performance of triage [28].

During the first wave of pandemic, a high number of people have been denied access to medical treatment, such as: COVID-19 patients who have been excluded from ICU due to overcrowding; non-tested COVID-19 patients (or tested *ex post*, even through autopsies) who have been excluded from medical care (including ICU) due to both overcrowding and the inefficiency of contact tracing measures and test capacity (e.g., scarcity of reagents, laboratories, or personnel); non-COVID-19 patients who have had their therapies suspended, especially in emergency cases related to their pathology.

Depending on the legal system of each country, some individuals could potentially file a claim and seek compensation for damages (against healthcare professionals, hospitals, Regions, or States) due to the breach of their right to health, to physical integrity and right to life (Article 2 of the European Convention on Human Rights), to the manifestation of the informed consent in the medical field (Article 8 of the European Convention on Human Rights) or on the basis of a contractual (e.g., the Italian doctrine of social contact) or Aquilian obligation.

We consider potential claims from patients who have not been denied healthcare deliveries during the pandemic as being part of the ordinary malpractice litigation rate, whose frequency can be found in previous literature [29]. Nevertheless, it would be reasonable to think that during the current pandemic the medical error risk could be increased by the emergency situation, since healthcare professionals (including those already retired, who were called back in) faced a high amount of stress, sleep deprivation due to multiple shifts and scarcity of resources, resulting, *inter alia*, in a low patient-nurse ratio, all factors that are known as contributing factor in medical errors [30]–[36], thus exposing them to malpractice claims.

Complaints regarding contagions in the workplace [37] (e.g. Amazon's employees before the French courts) and regarding extreme work conditions [38] can be filed too, however the matter is beyond our scope, because from a legal point of view the issue has a different nature: with the refusal of admission to the ICU the patient faces and immediate life threat, while the employee can avoid the contagion using special DIPs provided by the employer [39]. In addition, employees have an insurance that covers the injuries occurred in the workplace [40] and other compensation methods can be applied [41].

In this context, predicting the litigation rate could be useful to assess the economic impact of disputes at a local and national level, so that hospital managements and public institutions can perform a cost benefits analysis to decide whether to invest resources to increase critical care surge capacity. It has to be taken into consideration, however, the limitation and prescription periods and their possible suspension, which will affect the litigation rate.

Understanding how many patients could fit in ICUs is crucial to local governments too, as the decision to transfer of COVID-19 patience to facilities other than public hospitals, when the latter are overloaded, could also lead to liability. In fact, if we look at the Italian case, in March 2020, in the above mentioned resolution of the Regional Council of Lombardy, it has been decided that half of the beds in nursing homes for the elderly had to be reserved for COVID-19 patients, which lead to an increase of death rates in these institutions [42]. Furthermore, it would be important to forecast the impact of disputes on judicial systems, especially those already burdened by the overload and the length of judicial proceedings, in order to stimulate future reforms towards a more efficient organization of the system. To the aim of estimating the occupancy of ICUs and drive decisions, we developed a predictive model, described in the next Section.

III. CLIP – COVID-19 LItigation Prediction

The primary objective of the CLIP forecasting decision support system is to support the prediction of the number, and consequently, the potential economic impact of actual or alternative healthcare emergencies (starting from COVID-19 experience but considering other similar viral outbreaks) in the future, even also considering the non-treated chronic and fragile patients.

Our methodology is based on the estimation of the hospitals' accesses during the COVID-19 pandemic, as well as the potential impact of treatments and healthcare interventions delays on the hospitals' waiting lists. In particular, we aim at predicting the number of ICU beds occupied by COVID-19 patients, during time, or in a future increase of cases or other healthcare emergencies, and also the possible evaluation of gaps between patient effectively treated and patients potentially to be treated, from a claim and lawsuits point of view, in order to understand the potential level of conflicts. To this aim, we developed a stochastic prediction model whose input data is the following:

- the time-series $\mathbf{A} = (a_1, \dots, a_t)$ of cumulative admitted patients after t days from the beginning of the pandemic;
- the number of ICU beds $\boldsymbol{\theta} = (\theta_1, \dots, \theta_t)$ available at time t.

For predicting the cumulative number of hospital admissions of COVID-19 patients, we performed a logistic regression according to the available time-series; the logistic model is later used to predict the future values of cumulative hospital admissions. The parameters of the logistic model were fit by solving the non-linear unbounded optimization problem using the Levenberg-Marquardt algorithm implemented in the SciPy python library [43] with a limit of 10^6 fitness evaluations.

As soon as future hospital admissions per day are predicted, they are processed by our stochastic prediction algorithm which forecasts the number of ICU beds occupied by COVID-19 patients in the future. Specifically, the algorithm considers the following assumptions:

- the percentage of admitted patients that will visit the ICU is equal to 41%;
- the number of days in ICU is distributed as a beta-Pert distribution with the following parameters: low = 0, high = 28, peak = 6. The sampling from the beta-Pert

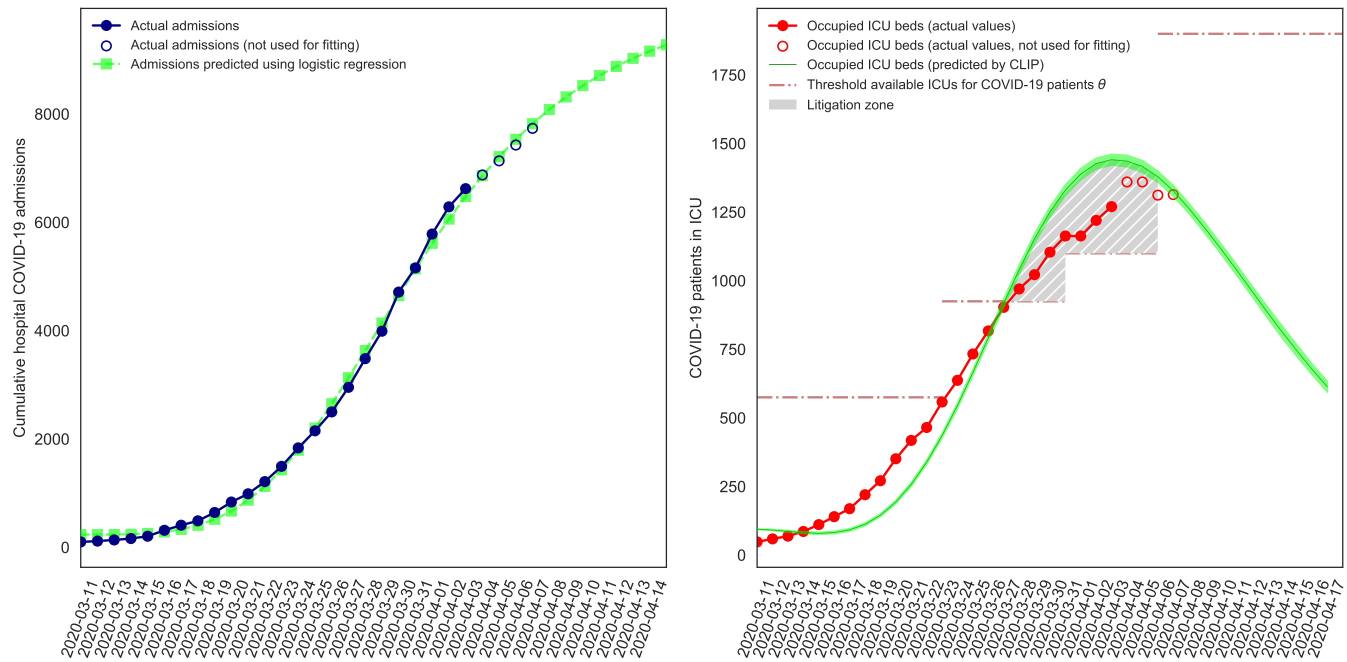

Fig. 1. Example of prediction provided by our models. On the left, we show the cumulative hospital admissions related to COVID-19 patients. The blue dots represent the actual data published by the government, up to April 6th, 2020. The green points represent the prediction provided by the logistic regression model. On the right, we show the number of occupied ICU beds estimated by CLIP (green points), compared to the actual number of admissions (red points). The thresholds of the ICU beds are denoted by the horizontal lines. The gray area highlights the "litigation zone", i.e., the days in which admitted patients requiring ICU exceeded the threshold.

distribution was performed using the TensorFlow Probability library;

- the patients enter the ICU immediately (i.e., we do not consider any time lag in both models).

These parameters were fit against the experimental data using the FST-PSO algorithm [44]. By using this information, we can perform a stochastic simulation of the number of new patience for each day. By repeating the simulation multiple times, we can calculate the mean and the standard deviation of the expected patients entering ICU. In this work, we assessed a statistics based on 100 repetitions.

By predicting the number of ICU beds that will be occupied by COVID-19 patients on a national level in the near future, the stochastic prediction models provide support for estimating the number of patients not admitted to the hospital for each day, i.e., exceeding the threshold θ_t. Currently, the models take only into account the public-available data mentioned above on a national level.

It is worth noting that access to data on a regional or hospital level might enable us to providing decision support in the near future for *(i)* upscaling decisions with regard to the number of ICU beds on regional and hospital level, and *(ii)* making decisions with regard to optimal transports between hospitals. Also, extending the model with information concerning the waiting lists and specific pathologies—e.g., patients from oncology departments or suffering from heart failures—could improve the precision of the model with other diseases of potential impact on mortality and also on possible claims, lawsuits, and related costs. Using the available information about the proportion of admitted patients requiring any care intensity hospitalization, and the different length of their stay in ICU, Sub-Intensive Care Units or Medical Units, the model will produce an estimation of the pressure on the different Units, as well as with the information concerning possible missing admissions and lawsuits. This methodology, in fact, will provide us with an approach useful to assess the expected number of people unable to obtain an hospital admission, along with a confidence interval.

Figure 1 shows an example of the prediction currently provided by our models, using the COVID-19 data provided by the Dutch government (RIVM and NVIC) during the first weeks of the pandemic. We exploited dutch data for this proof of concept because of the high quality of public data and the fact that the virus was spread across the whole country, instead of being confined to specific regions (see, e.g., the case of the first coronavirus outbreak in Italy). In our tests, we used the data up to April 2nd, 2020 for the calibration of the model and left the remaining 4 days as validation.

The information about the thresholds was collected from the COVID-19 Health Systems Response Monitor (HSRM) website [45]. In the left panel of Figure 1 we show the fitting of the logistic model (green square dots) against the historical data about the cumulative hospital COVID-19 admissions (blue circle dots).

In the right panel, we show how the predicted number of occupied ICU beds (green line) fits with respect to the observed data (red dots). The lime filled area around the prediction highlights the standard deviation calculated by the stochastic algorithm. The horizontal lines represent the thresholds $\boldsymbol{\theta}$ of available ICU beds. When the predicted number of occupied ICU beds exceed the available resources, we enter the "litigation zone", as evidenced by the gray filled area. Each individual admitted to the hospital but rejected from a ICU due to the lack of resources is considered a potential claim. It is worth noting that the actual number of ICU beds occupied exceeded the threshold thanks to the redistribution of patients outside the country (e.g., to Germany [46]).

IV. Discussion and future developments

The fast spreading COVID-19 pandemic poses new questions, challenges and opportunities for the healthcare systems worldwide. This has led healthcare systems, both public and private, to face an unprecedented challenge to meet the needs of people becoming infected and eventually needing hospitalization and ICU care. In this view, the development and the availability of such a predictive model, that could further be used within other clinical conditions and important diseases, could help policy-makers in taking decisions under conditions of uncertainty. The implementation of this model become more difficult when the "state of emergency" is declared by law, since the effect of the measures (such as lockdown, closing of restaurants, gyms, clubs, etc.) has an impact on the natural spread of the virus, thus affecting the prediction and reducing its impact in the real clinical practice. Also, the differences in the management of the healthcare service at a regional level within a single Country (e.g., in Italy, according to its Constitution) could have an impact on the results at a national level. In addiction, it has to be noted that the restrictions to the Court activities have an obvious impact on lawsuits rates, since plaintiffs are prevented from filing not-urgent complaints. According to the above, the development of such a framework relying on data derived from other European Countries, could not only demonstrated its generalizability and replicability, but could be an improvement factor for taking decisions in both universal-based and insurance-based hospitals. Finally, although CLIP was designed to be used in a public healthcare system (i.e., at the institutional level), we want to stress the fact that it could also be exploited at hospital level (i.e., meso level) by calibrating the model with fine-grained admission data collected in that specific organization.

CLIP exploits logistic regression on the number of admitted patients and integrates a stochastic prediction model, whose probabilistic parameters were fit with swarm intelligence against the number of occupied ICU beds. More sophisticated approaches for time-series forecasting exist, most notably deep neural networks (e.g., Long Short-Time Memory recurrent networks); however, due to the limited amount of available time-series, this approach was not feasible in this preliminary work and will be investigated as future development.

From a legal point of view, a comparative approach, combined with previous studies [47], [48], could be helpful to assess the future litigation rate and outcome in the COVID-19 pandemic, in order to perform a cost/benefit evaluation both for public administration and hospital management. Additional research is needed to assess the ethical implications and the liability of States in managing the ICU units when their system capacity is reached.

As future development, CLIP will be extended to support the simulation of complex events (e.g., lockdowns, social distancing) in order to improve the quality of the predictions over long periods of time.

References

[1] M. Abir, C. Nelson, E. W. Chan, H. Al-Ibrahim, C. Cutter, K. Patel, and A. Bogart, "Critical care surge response strategies for the 2020 COVID-19 outbreak in the united states," *Retrieved from RAND Corporation: https://www. rand. org/content/dam/rand/pubs/research_reports/RRA100/RRA164-1/RAND_RRA164-1. pdf*, 2020.

[2] M. J. Gilmartin and T. A. D'Aunno, "Leadership research in healthcare: A review and roadmap," *Academy of Management Annals*, vol. 1, no. 1, pp. 387–438, 2007.

[3] E. Grigoroudis and Y. Siskos, "Preference disaggregation for measuring and analysing customer satisfaction: The MUSA method," *European Journal of Operational Research*, vol. 143, no. 1, pp. 148–170, 2002.

[4] A. Gagliano, P. G. Villani, A. Manelli, S. Paglia, P. A. Bisagni, G. M. Perotti, E. Storti, M. Lombardo *et al.*, "COVID-19 epidemic in the middle province of Northern Italy: impact, logistics, and strategy in the first line hospital," *Disaster medicine and public health preparedness*, pp. 1–5, 2020.

[5] C. Miani, E. Robin, V. Horvath, C. Manville, J. Cave, and J. Chataway, "Health and healthcare: assessing the real world data policy landscape in Europe," *Rand health quarterly*, vol. 4, no. 2, 2014.

[6] S. Consoli, D. R. Recupero, and M. Petkovic, *Data Science for Healthcare*. Springer, 2019.

[7] L. N. Sanchez-Pinto, Y. Luo, and M. M. Churpek, "Big data and data science in critical care," *Chest*, vol. 154, no. 5, pp. 1239–1248, 2018.

[8] N. I. of Health *et al.*, "COVID-19 Treatment Guidelines Panel," *Coronavirus disease*, 2019.

[9] "NHS coronavirus specialty guides," https://www.england.nhs.uk/coronavirus/secondary-care/other-resources/specialty-guides/, accessed: 2020-10-15.

[10] "SAMW – intensive care medicine: triage in case of bottlenecks," https://www.samw.ch/en/Ethics/Topics-A-to-Z/Intensive-care-medicine.html, accessed: 2020-10-15.

[11] "NHG – Triage thuisbehandeling versus verwijzen naar het ziekenhuis bij oudere patiënt met (verdenking op) COVID-19 (pdf)," https://www.nhg.org/sites/default/files/content/nhg_org/uploads/20200327_fms_leidraad_triage_thuisbehandeling_verwijzen_oudere_verdenking_covid19.pdf, accessed: 2020-10-15.

[12] S. Salleh, P. Thokala, A. Brennan, R. Hughes, and A. Booth, "Simulation modelling in healthcare: an umbrella review of systematic literature reviews," *PharmacoEconomics*, vol. 35, no. 9, pp. 937–949, 2017.

[13] A. Cheng, W. Eppich, T. Sawyer, and V. Grant, "Debriefing: the state of the art and science in healthcare simulation," *Healthcare simulation education: evidence, theory and practice. Chichester: Wiley*, pp. 158–64, 2018.

[14] S. Brailsford and J. Klien, "The value of modeling and simulation in healthcare: A review of the evidence and some possible ways forward," in *Cumberland Initiative*. Brunel University, 2015.

[15] M. Gul and A. F. Guneri, "A comprehensive review of emergency department simulation applications for normal and disaster conditions," *Computers & Industrial Engineering*, vol. 83, pp. 327–344, 2015.

[16] M. G. Faure and H. Koziol, "Cases on medical malpractice in a comparative perspective," *Tort and Insurance Law*, no. 1, 2001.

[17] M. Kirby, "Medical negligence-going Dutch," *Australian Journal of Forensic Sciences*, vol. 33, no. 2, pp. 59–60, 2001.

[18] D. Klemann, M. ten Hoopen, and H. Mertens, "Medische aansprakelijkheid in nederland: Tijd voor een no faultsysteem?" *Nederlands Juristenblad*, no. 39, pp. 2932–2944, 2019.

[19] H. Li, S. Dong, Z. Liao, Y. Yao, S. Yuan, Y. Cui, and G. Li, "Retrospective analysis of medical malpractice claims in tertiary hospitals of China: the view from patient safety," *BMJ open*, vol. 10, no. 9, p. e034681, 2020.

[20] A. C. Schaffer, A. B. Jena, S. A. Seabury, H. Singh, V. Chalasani, and A. Kachalia, "Rates and characteristics of paid malpractice claims among US physicians by specialty, 1992-2014," *JAMA internal medicine*, vol. 177, no. 5, pp. 710–718, 2017.

[21] A. B. Jena, L. Schoemaker, J. Bhattacharya, and S. A. Seabury, "Physician spending and subsequent risk of malpractice claims: observational study," *BMJ*, 2015.

[22] P. G. Peters, "Twenty years of evidence on the outcomes of malpractice claims," *Clinical orthopaedics and related research*, vol. 467, no. 2, pp. 352–357, 2009.

[23] Z. Wang, N. Li, M. Jiang, K. Dear, and C.-R. Hsieh, "Records of medical malpractice litigation: a potential indicator of health-care quality in China," *Bulletin of the World Health Organization*, vol. 95, no. 6, p. 430, 2017.

[24] G. Bonalumi, M. di Mauro, A. Garatti, F. Barili, G. Gerosa, A. Parolari, and I. S. for Cardiac Surgery Task Force on COVID-19 Pandemic, "The COVID-19 outbreak and its impact on hospitals in Italy: the model of cardiac surgery," 2020.

[25] P. Barach, S. D. Fisher, M. J. Adams, G. R. Burstein, P. D. Brophy, D. Z. Kuo, and S. E. Lipshultz, "Disruption of healthcare: Will the COVID pandemic worsen non-COVID outcomes and disease outbreaks?" *Progress in Pediatric Cardiology*, 2020.

[26] B. Chen and D. M. McNamara, "Disability Discrimination, Medical Rationing and COVID-19," *Asian bioethics review*, pp. 1–8, 2020.

[27] A. Oliva, M. Caputo, S. Grassi, G. Vetrugno, M. Marazza, G. Ponzanelli, R. Cauda, G. Scambia, G. Forti, R. Bellantone *et al.*, "Liability of Health Care Professionals and Institutions During COVID-19 Pandemic in Italy: Symposium Proceedings and Position Statement," *Journal of Patient Safety*, 2019.

[28] S. Aziz, Y. M. Arabi, W. Alhazzani, L. Evans, G. Citerio, K. Fischkoff, J. Salluh, G. Meyfroidt, F. Alshamsi, S. Oczkowski *et al.*, "Managing ICU surge during the COVID-19 crisis: rapid guidelines." *Intensive Care Medicine*, 2020.

[29] K. D. Hart and P. G. Peters, "Cultures of claiming: Local variation in malpractice claim frequency," *Journal of Empirical Legal Studies*, vol. 5, no. 1, pp. 77–107, 2008.

[30] N. S. Weingart, R. M. Wilson, R. W. Gibberd, and B. Harrison, "Epidemiology of medical error," *BMJ*, vol. 320, no. 7237, pp. 774–777, 2000.

[31] L. H. Aiken, S. P. Clarke, D. M. Sloane, J. Sochalski, and J. H. Silber, "Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction," *JAMA*, vol. 288, no. 16, pp. 1987–1993, 2002.

[32] C. P. Landrigan, J. M. Rothschild, J. W. Cronin, R. Kaushal, E. Burdick, J. T. Katz, C. M. Lilly, P. H. Stone, S. W. Lockley, D. W. Bates *et al.*, "Effect of reducing interns' work hours on serious medical errors in intensive care units," *New England Journal of Medicine*, vol. 351, no. 18, pp. 1838–1848, 2004.

[33] L. K. Barger, N. T. Ayas, B. E. Cade, J. W. Cronin, B. Rosner, F. E. Speizer, and C. A. Czeisler, "Impact of extended-duration shifts on medical errors, adverse events, and attentional failures," *PLoS Medicine*, vol. 3, no. 12, p. e487, 2006.

[34] P. A. Palmieri, P. R. DeLucia, L. T. Peterson, T. E. Ott, and A. Green, "The anatomy and physiology of error in adverse health care events," in *Patient safety and health care management*. Emerald Group Publishing Limited, 2008.

[35] A. M. Fahrenkopf, T. C. Sectish, L. K. Barger, P. J. Sharek, D. Lewin, V. W. Chiang, S. Edwards, B. L. Wiedermann, and C. P. Landrigan, "Rates of medication errors among depressed and burnt out residents: prospective cohort study," *BMJ*, vol. 336, no. 7642, pp. 488–491, 2008.

[36] D. M. Abdulah, K. A. Perot, and E. Holroyd, "Fatigue as a primary and secondary factor in relation to shift-rotating and patient safety in nurses," *Journal of Hospital Administration*, vol. 9, no. 1, 2020.

[37] P. Sandulli, A. Pandolfo, and M. Faioli, "Coronavirus e responsabilità datoriale da infortunio sul lavoro," *Rivista del Diritto della Sicurezza Sociale*, vol. 20, no. 3, pp. 631–641, 2020.

[38] J. Atkinson, "COVID-19 and employee rights: securing the right to safe working conditions," *British Policy and Politics at LSE*, 2020.

[39] L. Cirrincione, F. Plescia, C. Ledda, V. Rapisarda, D. Martorana, R. E. Moldovan, K. Theodoridou, and E. Cannizzaro, "COVID-19 pandemic: Prevention and protection measures to be adopted at the workplace," *Sustainability*, vol. 12, no. 9, p. 3603, 2020.

[40] G. Ludovico, "Il contagio da COVID-19 come infortunio sul lavoro tra copertura INAIL e responsabilità civile," *Rivista del Diritto della Sicurezza Sociale*, vol. 20, no. 2, pp. 353–364, 2020.

[41] J. L. Gelman, "Lessons from asbestos litigation apply to COVID claims," *Available at SSRN 3659568*, 2020.

[42] S. Logar, "Care home facilities as new COVID-19 hotspots: Lombardy Region (Italy) case study," *Archives of gerontology and geriatrics*, vol. 89, p. 104087, 2020.

[43] P. Virtanen, R. Gommers, T. E. Oliphant, M. Haberland, T. Reddy, D. Cournapeau, E. Burovski, P. Peterson, W. Weckesser, J. Bright *et al.*, "Scipy 1.0: fundamental algorithms for scientific computing in python," *Nature methods*, vol. 17, no. 3, pp. 261–272, 2020.

[44] M. S. Nobile, P. Cazzaniga, D. Besozzi, R. Colombo, G. Mauri, and G. Pasi, "Fuzzy Self-Tuning PSO: A settings-free algorithm for global optimization," *Swarm and evolutionary computation*, vol. 39, pp. 70–85, 2018.

[45] WHO Regional Office for Europe, *COVID-19 Health System Response Monitor (Policy responses for Netherlands)*, 2020. [Online]. Available: https://www.covid19healthsystem.org/countries/netherlands/livinghit.aspx?Section=2.1%20Physical%20infrastructure&Type=Section

[46] NL Times, *COVID-19 deaths, hospitalizations keep falling; Most patients had underlying health problems*, April 2020. [Online]. Available: https://nltimes.nl/2020/04/07/covid-19-deaths-hospitalizations-keep-falling-patients-underlying-health-problems

[47] M. Bonetti, P. Cirillo, P. Musile Tanzi, and E. Trinchero, "An analysis of the number of medical malpractice claims and their amounts," *Plos one*, vol. 11, no. 4, p. e0153362, 2016.

[48] J. B. Rubin and T. F. Bishop, "Characteristics of paid malpractice claims settled in and out of court in the USA: a retrospective analysis," *BMJ open*, vol. 3, no. 6, 2013.