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Review

COVID-19 impact analysis on patients with complex health conditions: A literature review

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Abstract: The COVID-19 pandemic has profoundly changed the world and human society in various ways. Infection-related figures are key indicators of the direct impact of the pandemic. In addition to the virus, many vulnerable populations (e.g. patients with complex health conditions) have suffered direct or indirect health impacts, such as delayed treatment or diagnosis of cancer and severe mental illness due to stay-at-home restrictions, or financial issues. Studying these kinds of impacts can provide the community with insights and understanding of how the pandemic has affected patients with health conditions and help inform decision-makers design policies that support various vulnerable populations. This paper surveys analytical work conducted on how COVID-19 has impacted patients with complex health conditions. We categorise vulnerable populations into three specific cohorts: patients with chronic disease, patients with cancer and patients with end-of-life care. We then investigate how each of these cohorts has been impacted by the pandemic. We also identify each cohort from an analytics perspective by leveraging various data collection strategies and analytical methods. The goals of this paper are to provide evidence on how to improve the quality of life for vulnerable populations and to inform a national response strategy for future pandemics, which seems inevitable in a highly globalised economy.

Keywords: COVID-19 Pandemic; Impact Analysis, Data Analytics; Health Care; Vulnerable Cohort; Complex Health Condition

1. Introduction

COVID-19 was first reported in December 2019 [1], then the World Health Organization (WHO) announced the pandemic in 2020 [2]. COVID-19 is very easily spread from person to person, similar to influenza. However, it is more deadly than influenza. In 2020, there were a total of 82,661,679 people infected with COVID-19, and 1,879,763 deaths [3]. The impact of the pandemic gradually decreased in 2021 due to increasing vaccination coverage. To date, several countries have already opened their economies and borders with nearly full vaccination rates, and most of the others have published clear plans to relieve restrictions upon reaching vaccination coverage targets.

Governments in different countries have used a range of strategies to tackle the pandemic. Moreover, in different stages of the pandemic, the national response strategies changed according to real-world impacts. Most of these strategies restricted peoples' movements in the physical world. This type of restriction strategy caused substantial economic losses to both domestic and international economies. The International Labour Organization reported that in 2020, global working hours decreased by 8.8 per cent compared to the fourth quarter of 2019, resulting in a loss of 255 million full-time jobs [4].

COVID-19 infections usually impact patients' upper respiratory systems, which makes them deadly. Even if patients recover from COVID-19, they can suffer some permanent side-effects, such as fatigue and shortness of breath. Patients' families can experience mental health issues or illnesses due to the loss of family members or the need for ongoing care. Moreover, many people have also

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suffered from mental health issues caused by the pandemic, such as financial pressures, loss of work, restricted household visits, and lack of face-to-face communication. In addition to these impacts, patients with complex health conditions are among the most vulnerable populations in the pandemic. Individuals who have compromised immune systems or pre-existing medical conditions, such as cancer, may be at a higher risk of contracting COVID-19 and experiencing more severe infections. As a result of the COVID-19 pandemic, individuals in this group have been reducing and postponing their visits to clinicians and pathology testing. Therefore, the health care for people with cancer may have been disrupted due to government policy decisions and limited health resources available during the COVID-19 pandemic.

Three kinds of patient groups are studied. The first group consists of patients who have chronic illnesses, including diabetes, cardiovascular disease, and severe mental illness. The second group is cancer patients who need continuous medical treatment to control the progression of the disease. The third group is patients receiving end-of-life care whose survival rate and quality of life are related to the quality of care received.

The pandemic's impact is studied using both qualitative and quantitative analytics. Medical-based quantitative analysis can give insights into the impact with logical reasoning, and data-driven qualitative analytics can provide evidence to support real-world impacts. With widespread digitisation and data collection techniques, many available datasets can be integrated to examine the impact on human life and services received. Moreover, the COVID-19 pandemic is also examined using various analytical methods, and these results and data sources may also be valuable for conducting impact analysis. Our main contributions are summarized as follows:

- This chapter surveys analytical work conducted on how COVID-19 has impacted patients with complex health conditions.
- We categorise vulnerable populations into three specific cohorts: patients with chronic disease, patients with cancer and patients with end-of-life care.
- We investigate how each of these cohorts has been impacted by the pandemic, and identify each cohort from an analytics perspective by leveraging various data collection strategies and analytical methods.

The remainder of this chapter is organized as follows. Section 2 reviews related works. Then, three specific cohorts are categorised in Section 3, 4 and 5. And next, in Section 6, we demonstrate the various data collection strategies and analytical methods. Lastly, we conclude the work in Section 7.

2. Related Work

2.1. COVID-19-Related Analytics by the Australian Government

The impact of the COVID-19 pandemic on health and welfare issues relevant in Australia has been analyzed in key publications such as the report from the Australian Institute of Health and Welfare (AIHW) [5]. The Australian Government Department of Health has collected rich information to record statistical information on COVID-19-related activities [6]. Additionally, the impacts of COVID-19 have been analyzed in a report published by The Treasury [7].

To aid in the understanding of the impacts of COVID-19, the Australian Bureau of Statistics (ABS) has made available several new statistical and research products [8]. These new products comprise further analysis and information on economic statistics, which cover the classification of COVID-19 policies, as well as selected issues in economic accounts and method changes. The Multi-Agency Data Integration Project (MADIP) has also developed expanded integrated data resources to support the COVID-19 response efforts [9].

Several health organizations in Australia have conducted analyses of service providers in response to the COVID-19 pandemic, focusing on specific cohorts. For instance, Cancer Australia investigated the impact of COVID-19 on medical services and procedures in Australia by analyzing Medicare

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Benefits Schedule (MBS) claims [10]. The study examined services for the five highest incidences of cancers, namely breast, colorectal, lung, prostate, and skin cancer-related services. The report revealed that service providers in Australia reported significant reductions in procedures related to cancer investigations and treatments due to the COVID-19 pandemic.

2.2. Stringency Index

To address the COVID-19 pandemic, governments have considered various measures across a wide range of areas. These tools have aimed to rigorously and consistently track and compare policy responses around the world. The Stringency Index [11] is one of the tools used to measure the governments' response metrics to COVID-19. This index was produced by the Oxford COVID-19 Government Response Tracker (OxCGRT) [12]. The index measures the severity of lockdown-style policies, which are primarily aimed at limiting people's behavior. The index is computed by taking into account all the ordinal containment and closure policy indicators, as well as an indicator that tracks public information campaigns.

Australia has employed the index as a metric to gauge the government's COVID-19 response, and it stood at a 68.06 on 21 July 2021, according to Spectator Australia [13]. The ABS has utilized the Stringency Index to rank the severity of movement restrictions and government responses in each of Australia's eight states and territories, based on archived official sources. The ABS has generated eight indices to measure the stringency of each state/territory's COVID-19 response, with a maximum score of 100 indicating the highest level of restrictions [14].

3. Impact on Patients with Chronic Diseases

Individuals who have chronic conditions face an increased risk of severe illness if they contract COVID-19. These people need protection from COVID-19 and should avoid exposure to the public if they are infected with the virus, which may disrupt their health care, such as scheduled appointments with their doctors. To facilitate the impact analysis of COVID-19, chronic diseases can be categorised as follows:

- High incidence chronic conditions: cardiovascular disease, diabetes, kidney disease and respiratory disease
- Neurological conditions: epilepsy and multiple sclerosis
- Eye and macular diseases, e.g. anti-VEGF (vascular endothelial growth factor) treatment
- Musculoskeletal diseases
- Chronic pain
- Endometriosis
- HIV
- Hepatitis
- Osteoporosis
- Rare diseases, e.g. spinal muscular atrophy (SMA) and cystic fibrosis
- Severe mental illnesses, including schizophrenia, psychotic disorders, bipolar disorder and major depression

3.1. Literature Review

Chronic conditions are a significant source of disability, ill health, and premature mortality, and are thus a critical health concern at the global, national, and individual levels. These conditions, also known as chronic diseases, non-communicable diseases, or long-term health conditions, are typically marked by persistent and long-lasting effects [15]. In this review, high-incidence chronic conditions include cardiovascular disease, diabetes, kidney disease, and respiratory disease, etc.

Cardiovascular diseases. Individuals with pre-existing cardiovascular conditions who contract COVID-19 face a greater risk of morbidity and mortality. [16]. Myocardial injury (MI) is present in more than 25 per cent of critical cases and presents in two patterns: acute MI and dysfunction

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on presentation and MI that develops as the illness severity intensifies. Furthermore, COVID-19 has been linked to a range of cardiovascular complications, such as MI and myocarditis, acute MI, heart failure, arrhythmia, stress-induced cardiomyopathy, venous thromboembolism (VTE), acute coronary syndrome, and disseminated intravascular coagulation (DIC). Due to concerns over potential cardiovascular complications associated with medications used to treat COVID-19 patients, their administration should be approached with caution and carefully evaluated before treatment [17]. Investigations by Ref. [18] have examined the effects of COVID-19 on the treatment of cardiovascular patients and the alterations in hospital logistics that may conflict with critical principles for treating patients with the acute coronary syndrome.

Diabetes. Patients with diabetes have been identified as having a higher risk for severe illness and mortality when infected with COVID-19 [19]. To this end, a set of measures has been studied for patients with diabetes. For example, in Ref. [20], The authors of the study compared the phenotypic characteristics of patients with diabetes mellitus and COVID-19 infections who were hospitalized versus those who were not, and developed a straightforward hospitalization prediction risk score. Ref. [21] studied individuals with diabetes are more likely to develop COVID-19 due to a number of potential mechanisms. [22] suggested a set of measures for individuals with diabetes who contract COVID-19, encompassing both specific and general preventive strategies. For instance, they recommended frequent blood glucose monitoring for hospitalized patients with severe disease.

Kidney disease. Studies have revealed a significant proportion of COVID-19 patients admitted to hospitals exhibiting signs of kidney dysfunction, as reported by Ref. [23]. These signs included proteinuria in 59 per cent of cases, hematuria in 44 per cent, increased levels of blood urea nitrogen in 14 per cent, and increased levels of serum creatinine in 10 per cent, which were mild but worse than those observed in cases of other forms of pneumonia. Researchers discovered a significant correlation between the mortality of COVID-19 patients and certain medical factors, including proteinuria, hematuria, elevated levels of blood urea nitrogen, serum creatinine, uric acid, and D-dimer (a protein fragment that is produced when a blood clot dissolves in the body), according to the results of a univariate Cox regression analysis.

According to the Cox regression analysis, COVID-19 patients who developed acute kidney injury (AKI) had a mortality risk approximately 5.3 times higher than those without AKI, which was considerably greater than the mortality risk associated with other comorbid chronic illnesses. It is worth noting that AKI has been observed in up to 25 per cent of critically ill COVID-19 patients, particularly in those with underlying comorbidities [24].

Respiratory disease. In Ref. [25], patients who tested positive for another respiratory virus were compared between those with and without COVID-19. They found that patients with COVID-19 had longer symptom durations and were more frequently hospitalized when compared to patients who tested positive for another respiratory virus but did not have COVID-19. However, there were no significant differences between the two groups in terms of most comorbidities, medications, symptoms, vital signs, laboratory test results, treatments, and outcomes. However, it is important to note that patients with COVID-19 who present with mild symptoms have a higher in-hospital mortality rate, which is linked to older age, platelet count, and ferritin levels. Clinical practitioners can benefit from identifying early predictors of outcomes to more effectively categorize and treat patients with COVID-19. Ref. [26,27] summarized the recommendations provided by the European Forum for Research and Education in Allergy and Airway Diseases (EUFOREA) expert teams on allergic airway diseases and allergen-specific immunotherapy (AIT). The review explored the similarities and differences between allergic rhinitis (AR) and coronavirus infection and provided tailored recommendations for managing allergic diseases during the COVID-19 era, including guidance on AIT. Ref. [28] conducted a study to investigate extra-respiratory manifestations related to COVID-19. Their aim was to assist clinicians in gaining a better understanding of the various clinical presentations associated with the disease.

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3.1.1. Neurological Conditions

Epilepsy. Epilepsy is a disorder in which nerve cell activity in the brain is disturbed, causing seizures [29]. There is currently no evidence to suggest that having a medical history of epilepsy increases the risk of developing COVID-19. Additionally, previous encounters with infectious diseases have not revealed any correlations [30]. Ref. [31] summarised the current evidence on the diverse impacts of COVID-19 on epilepsy. Ref. [32] conducted a study in southwest China comparing the level of psychological distress between patients with epilepsy and healthy individuals during the COVID-19 pandemic. The study also aimed to identify potential risk factors for severe psychological distress among patients with epilepsy. Ref. [33] conducted a survey on the impact of the COVID-19 pandemic on epilepsy patients. The study revealed that epilepsy patients have been affected by the pandemic, and those with tumour-related, drug-resistant epilepsy, insomnia, and economic difficulties are at a higher risk of increased seizure frequency.

Multiple sclerosis. Multiple sclerosis (MS) disrupts nerve impulses in the central nervous system, which includes the brain, spinal cord, and optic nerves [34]. This autoimmune disease attacks the body's own nervous system. In a study cited as Ref. [35], the severity of COVID-19 was evaluated in patients with multiple sclerosis, Parkinson's disease, and cognitive impairment using a questionnaire-based approach. The study observed that patients who tested positive for COVID-19 by reverse transcription polymerase chain reaction (RT-PCR) did not show any clinical symptoms of the infectious disease. Additionally, there were no significant alterations in the neurological status of patients during the progression of their primary nervous system disease. Ref. [36] highlighted the impact of COVID-19 on individuals with multiple sclerosis (MS) and related disorders. They specifically discussed the increased risk of respiratory infections and provided general health advice based on consensus-based guidelines for managing immunotherapy, relapses, and service delivery during the pandemic. Additionally, Ref. [37] recommended the establishment of a data collection program to assess the correlation between MS and COVID-19. They also suggested implementing timely and effective protective measures accordingly.

3.1.2. Eye and Macular Diseases

Macular degeneration is an eye disease that can cause vision loss. Dry macular degeneration is characterized by the deterioration of the center of the retina, resulting in the loss of the central field of vision, while wet macular degeneration involves the growth of leaky blood vessels under the retina [38]. Ref. [39] evaluated the impact of the COVID-19 lockdown on patients with macular edema who received intravitreal injections, finding that delayed treatment resulted in varied outcomes. The authors suggested that prioritizing patients based on the equity principle of bioethics, where those in urgent need are prioritized over others depending on potential adverse outcomes, may help triage patients in need of treatment. Furthermore, Ref. [40] demonstrated a proof-of-concept calculation that determines the health-adjusted life-year trade-off between the transmission of COVID-19 and intravitreal anti-VEGF (vascular endothelial growth factor) injections. To reduce the risk of disease transmission, clinical ophthalmological guidelines advise evaluating potential benefits and harms before deciding whether to carry out elective ophthalmology procedures amidst the COVID-19 pandemic.

3.1.3. Musculoskeletal Diseases

Ref. [41] examined how COVID-19 outcomes in patients with rheumatic and musculoskeletal diseases have changed over the course of the pandemic. The researchers analyzed various outcomes, including hospitalization, ICU admission, mechanical ventilation, renal failure, and death, which occurred within 30 days of COVID-19 diagnosis. Ref. [42] conducted a study to explore the musculoskeletal implications of COVID-19. The study summarized known musculoskeletal pathologies in patients with SARS or COVID-19, and utilized computational modeling and

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biochemical signaling research to anticipate the cellular targets and long-term effects of the disease on musculoskeletal well-being. Ref. [43] offered guidance to healthcare providers in rheumatology on how to use COVID-19 vaccines for patients with rheumatic and musculoskeletal diseases (RMD). The authors provided advice on the best vaccination strategies for RMD patients and how to implement them effectively.

3.1.4. Chronic Pain

Chronic pain is a common aspect of quality of life, but the impact of this additional comorbidity on critical care survivors is not well understood. Estimates of chronic pain prevalence following ICU treatment range from 14 per cent to 77 per cent, depending on the measurement method, time scale, and population studied [44]. Survivors of critical illness from COVID-19 are particularly vulnerable to developing chronic pain. When it comes to chronic pain, it is crucial to view it in the context of a biopsychosocial model, which acknowledges that symptoms result from intricate and dynamic interactions among biological, psychological, and social factors [45]. Healthcare providers who are responsible for managing patients with chronic pain must take into account several interrelated factors, including the public health impact of COVID-19 on these patients, the consequences of not treating them during the pandemic, the available options for remote assessment and management, and the clinical evidence supporting remote therapies. Both Ref. [46] and Ref. [47] emphasize the importance of considering these factors when providing care to patients with chronic pain during the COVID-19 pandemic.

3.1.5. Endometriosis

Endometriosis is a chronic pain condition that affects premenopausal women. During the COVID-19 pandemic, a web-based cross-sectional survey was conducted in Germany to investigate the pain experience and social support of endometriosis patients [48]. The survey found that emotional and social pain, as well as physical pain and disability, were affected differently by emotional, social, and healthcare constraints related to the pandemic. The COVID-19 pandemic has significantly impacted the clinical practice of women's health and routine care for endometriosis. Ref. [49] offered clinical guidance on managing endometriosis during the pandemic and discusses future considerations.

3.1.6. HIV

The COVID-19 pandemic has posed numerous challenges to the HIV care continuum, as noted by Ref. [50]. While there was a slight increase in ICU admission, mechanical ventilation, and mortality rates among HIV-positive patients, these differences were not statistically significant [51]. However, the pandemic has had a significant impact on HIV care. First, measures such as quarantine, social distancing, and community containment have limited access to routine HIV testing, especially in areas with limited testing kits. Therefore, efforts are needed to improve access to testing. Second, access to timely HIV care may have been hindered by the pandemic, as antiretroviral therapy initiation and continuation may have been delayed or deterred due to hospitals being overwhelmed by COVID-19 patients and resource allocation challenges. Third, the COVID-19 pandemic may have also affected antiretroviral therapy continuation.

3.1.7. Hepatitis

The global survey conducted by the World Hepatitis Alliance, which represents over 300 member organizations in 99 countries, aimed to assess the impact of COVID-19 on viral hepatitis services and individuals living with the disease [52]. Out of 132 respondents, only 47 (36 per cent) were able to access viral hepatitis testing. Of the 101 respondents who provided reasons for their inability to access testing, 46 cited the closure of testing facilities as the main issue. This closure was reported by 16 of the 54 respondents (30 per cent) who were located outside the United States. Additionally, 66 out of 101 respondents (65 per cent) believed that another reason for the lack of testing access was due to

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COVID-19. In terms of medication access, 23 out of 68 respondents (34 per cent) who were located outside the United States were unable to obtain their medications during the pandemic, particularly in low- and middle-income countries (LMICs). In contrast, only 5 out of 64 respondents (8 per cent) from the United States were unable to access treatment during the pandemic. Out of 64 respondents who reported a lack of access to treatment, 32 (50 per cent) felt that people were avoiding healthcare facilities due to COVID-19, with 14 out of 22 LMIC respondents (64 per cent) expressing this concern. Another concern was the absence of targeted guidance on COVID-19 for individuals who have viral hepatitis, with only 39 out of 131 (30per cent) respondents indicating that sufficient information had been provided in their country [53].

3.1.8. Osteoporosis

Osteoporosis, being a chronic condition, usually demands long-term medical treatment to prevent further bone loss, compromised skeletal strength, and fractures. However, abruptly stopping some therapies can heighten the risk of harm. Compounding this issue, the COVID-19 pandemic has caused unprecedented disruption to healthcare worldwide, with almost universal calls for social distancing [54].

3.1.9. Rare Diseases

According to a study [55] conducted in Hong Kong, the COVID-19 pandemic had a significant impact on rare disease patients. The study used a cross-sectional online survey in April 2020 to gather the perspectives of 272 patients with 89 distinct rare diseases and their caregivers. The results showed that the pandemic affected various aspects of the patients' lives, including their health status (46 per cent), service use patterns (71 per cent), mental health (79 per cent), daily living (82 per cent), social life (92 per cent), and financial status (81per cent). Patients who had any level of dependency, as measured by the Barthel Index for Activities of Daily Living, experienced more significant impacts on their health status, medical status, rehabilitation, and mental health due to the pandemic compared to those who were fully independent.

3.1.10. Severe Mental Illness

Recent research has indicated that individuals with severe mental illnesses and psychotic disorders face a notably increased risk of mortality associated with COVID-19. In one study [56], the authors discovered that a significant gap in survival rates persisted between those without schizophrenia and those with the condition throughout the first year of the pandemic, contributing to a growing body of evidence on the subject. a different study [57] reported that the finding of patients with dependency being more affected by the pandemic did not result in specific interventions or better outcomes for these patients. In fact, during the latter half of the follow-up period, the gap in mortality rates was found to be larger, with higher rates of COVID-19-associated hospital admissions for people with schizophrenia in Israel. While other studies have replicated these findings, the results have been somewhat equivocal, possibly due to differences in healthcare systems and patients' access to care [56].

Chronic disease patients are at higher risk of severe COVID-19 illness and face the potential worsening of pre-existing conditions due to care disruptions [58]. In Australia, Belgium, and the Netherlands, telehealth services, self-management support, proactive care, community partnerships, and funding model reform have helped support chronic disease management during the pandemic. To ensure equitable access to care, it is essential to address the digital divide and provide continued support to vulnerable patients who may be isolated during lockdowns. Electronic medical records can help identify and monitor vulnerable patients, and community partnerships can foster innovation and enhance continuity of care. Additionally, given the anticipated increase in chronic conditions and complications, funding model reform should be considered urgently, especially in regions where healthcare disruptions have been significant.

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3.2. Conclusion

The impact of COVID-19 on people with chronic diseases, or those at risk of developing them, cannot be overstated. In this section, we examined the effects of the pandemic on patients with high-incidence chronic diseases. COVID-19 has disrupted disease management and impeded chronic disease prevention efforts [59]. Individuals who have pre-existing medical conditions, including hypertension, diabetes, and coronary heart disease, are at a higher risk of developing severe COVID-19. Those with cardiovascular diseases are also at a higher risk of mortality. Patients with immunosuppressive chronic diseases like HIV, diabetes, and kidney disease are more vulnerable to infections and are less likely to recover from COVID-19. In fact, COVID-19 is now a leading cause of heart disease, responsible for approximately 5 per cent of acute heart failure cases [60].

4. Impact on Patients with Cancer

The COVID-19 pandemic has presented additional obstacles for cancer patients. Individuals with weakened immune systems or pre-existing medical conditions may be more susceptible to COVID-19 and its severe effects. Furthermore, due to the decreased availability of medical services, some cancer patients have postponed their appointments with clinicians and pathology testing.

To investigate the effect of COVID-19 on medical services and procedures for cancer patients in Australia, Cancer Australia [10] analyzed MBS claims. The results revealed that there was a nationwide decline in the number of diagnostic and therapeutic procedures, including those related to breast, colorectal, lung, prostate, and skin cancers, during the initial COVID-19 period between March and May 2020. The decrease occurred primarily between March and April 2020, with more significant declines observed in April and May 2020 for some procedure categories.

4.1. Literature Review

4.1.1. Bladder Cancer

The COVID-19 pandemic has caused delays in diagnosis and therapy for most bladder cancer patients. According to a study [61], the fatality rate of bladder cancer outweighed that of COVID-19, with a potential fatality rate as high as 52 per cent. The study proposed a new approach to screening and monitoring bladder cancer, taking into account its aggressiveness and progression capacity based on its stage. According to Ref. [62], bladder cancer diagnoses and management were delayed during the pandemic, which resulted in higher fatality rates. The delays increased the risk of undetected and untreated bladder cancer cases, causing a surge in advanced cases during the pandemic. This surge of advanced bladder cancer cases is expected to contribute to the increased demand for cancer-related services after the pandemic is over.

4.1.2. Breast Cancer

Breast cancer patients have encountered delays in receiving diagnoses and treatment due to the COVID-19 pandemic. According to a report from Ref. [63], various aspects of breast cancer care have experienced delays, such as routine clinical visits (32 per cent), surveillance imaging (14 per cent), routine mammograms (11 per cent), reconstructions (10 per cent), radiation therapy (5 per cent), hormonal therapy (5 per cent), mastectomies (5 per cent), and chemotherapy (4 per cent). Roughly 30 per cent of patients chose to delay or alter their treatment plans due to concerns about contracting COVID-19, while about 30 per cent experienced no delays. The report also revealed that COVID-19 impacted the desire or ability of about 11 per cent of patients to seek a second opinion. Moreover, some standard chemotherapy drugs for breast cancer, including Taxol, Taxotere, Cytoxan, and carboplatin, as well as certain targeted therapies like Ibrance, Kisqali, Verzenio, and Piqray, can weaken the immune system, putting patients at a higher risk of developing infections like COVID-19. It is still uncertain

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whether patients who received these treatments in the past have an increased risk of developing severe COVID-19 complications.

4.1.3. Colon and Rectal Cancer

According to a report [64], the impact of the COVID-19 pandemic on colon and rectal cancer (CRC) patients has been limited. While there has been a significant decrease in outpatient volumes, especially for non-local and elderly patients, the number of chemotherapy and surgery procedures has remained constant. Among the 710 CRC patients who underwent curative resection, 49.4 per cent received laparoscopic surgeries, which was significantly higher than the 39.5 per cent recorded during the same period in 2019. Although the proportion of major complications during the pandemic was not significantly different from the control group, the average length of hospital stay was longer. These findings indicate that CRC patients who are confirmed to be free of infection can receive regular treatment, and online medical counseling and appropriate identification can effectively maintain treatment and follow-up. While adjuvant and palliative chemotherapy should continue, elective, palliative, and multidisciplinary surgeries as well as endoscopic polypectomy can be postponed. Nevertheless, curative surgery should be carried out normally. For older patients with colorectal cancer (CRC), neoadjuvant radiotherapy and endoscopic surgery are advised.

In another study [65], the prevalence of COVID-19 infection among CRC patients was found to be 45.1 per cent. While this demonstrates a high infection rate among these patients, there is no significant correlation between COVID-19 infection and CRC patients in the global population.

4.1.4. Kidney Cancer (Renal Cell and Renal Pelvis)

Kidney cancer is a type of cancer that originates in the cells of the kidney, with renal cell carcinoma (RCC) being the most common type, accounting for about 90 per cent of all cases [66]. However, the impact of COVID-19 on the mortality of kidney cancer patients is not yet clear. According to a report [67], the overall mortality rate of COVID-19 patients with kidney cancer was lower (11.8 per cent) compared to those with other types of cancer. Nevertheless, several other studies, including the Thoracic Cancers International COVID-19 Collaboration (TERAVOLT) international registry for patients with thoracic tumors, as well as French and Spanish registries, have shown a higher mortality rate (ranging from 14.6 to 34.6 per cent) and hospitalization rate (ranging from 72.4 to 76 per cent) among kidney cancer patients who contracted COVID-19.

4.1.5. Leukaemia

Leukemia refers to a group of cancers that affect the blood cells, and the type of leukemia depends on the blood cell that becomes cancerous and how quickly it grows [68]. However, COVID-19 can lead to fatal complications for patients with various types of leukemia. According to a convincing report [69], patients with haematological malignancies, who already have immunodeficiency due to the disease and its treatments, may be at a high risk of developing severe COVID-19 disease. Two initial international surveys conducted during the beginning of the COVID-19 pandemic found that CLL patients who were hospitalized with COVID-19 had a high mortality rate of over 30 per cent. However, these findings may not be fully representative of all CLL patients as they were based on a limited sample of patients from different sources and included only severe cases.

4.1.6. Liver and Bile Duct Cancer

The COVID-19 pandemic has presented unprecedented challenges to healthcare systems, and liver cancer patients may have been heavily impacted. Liver cancer patients, who are often older, have multiple comorbidities, and suffer from underlying liver disease, are a highly vulnerable category and appear to be at higher risk of mortality, particularly if they have undergone recent surgery or systemic treatment. The baseline dysfunction of both innate and adaptive immune responses in these patients adds to their vulnerability [70]. A study by Ref. [71] investigated whether the COVID-19 pandemic led

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to interruptions or delays in liver cancer screening or procedures. The results indicated that the first wave of the pandemic had a significant impact on the routine care of liver cancer patients, potentially resulting in impaired outcomes due to modifications in screening, diagnostic and treatment protocols.

4.1.7. Lung Cancer (Including Bronchus)

COVID-19 can cause acute respiratory distress syndrome, requiring advanced medical care like invasive mechanical ventilation for many patients [72]. While the study investigated the impact of COVID-19 on the immune system, lung ground glass opacity, and potential neoplastic changes, clinicians faced challenges in distinguishing COVID-19 super-infections from lung cancer progression [73]. Treatment of lung cancer patients during the pandemic required a practical multidisciplinary and international approach due to the lack of evidence in many areas [74]. Ref. [75] reported that COVID-19 was severe in patients with lung cancer, with 62 per cent requiring hospitalization and 25 per cent dying. However, COVID-19 accounted for only 11 per cent of overall lung cancer deaths during the pandemic. The severity of COVID-19 was not affected by cancer-specific features, such as prior thoracic surgery/radiation and recent systemic therapies. Moreover, hydroxychloroquine did not show any improvement in COVID-19 outcomes among hospitalized patients.

4.1.8. Melanoma

The COVID-19 pandemic has caused the postponement of planned medical and surgical procedures, which has resulted in delays in melanoma diagnosis and treatment for the dermatology community. However, neglecting melanoma can lead to increased morbidity, mortality, and healthcare costs [76]. In view of the recommendations from major oncologic societies and clinical practice, Ref. [77] suggested several measures for managing melanoma patients during the pandemic. These measures include encouraging patients to continue their ongoing target therapy or immunotherapy, contacting their oncologist or dermato-oncologist immediately in case of flu symptoms, performing a swab test before initiating or continuing medical chemotherapy/immunotherapy, or in the case of major surgeries that require frequent hospital visits, and evaluating COVID-19-positive patients on a case-by-case basis, potentially suspending treatment cycles if deemed necessary for either therapy.

4.1.9. Non-Hodgkin's Lymphoma

Patients with B-cell Non-Hodgkin's lymphoma (B-NHL), particularly those recently treated with anti-CD20 antibodies, are at high risk of severe COVID-19 [78]. Another emerging issue for patients with lymphoma or immune deficiency is prolonged COVID-19. Ref. [79] investigated the prolonged length of in-hospital stays among patients with lymphoma due to COVID-19, examining its determinants and outcomes. The findings of Ref. [79] may aid in the management of lymphoma during the pandemic, helping clinicians evaluate specific therapeutic approaches and explore questions on the efficacy and timing of vaccinations for this population.

4.1.10. Pancreatic Cancer

The impact of the COVID-19 pandemic on pancreatic cancer surgeries prompted Ref. [80] to examine guidelines for preventing the spread of viral infections in surgical environments during the pandemic. The paper recommended maintaining the activity of high-volume centres for pancreatic surgery and implementing telemedicine. Ref. [81] suggested improving oncological outcomes by using the neoadjuvant treatment and conducting safe surgeries in a controlled environment while delaying high-risk pancreatectomies to redirect resources towards COVID-19 cases. Ref. [82] recommended that treatment decisions for patients with pancreatic cancer be individualized based on multidisciplinary team discussions and comprehensive counselling on treatment options prior to obtaining informed consent.

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4.1.11. Prostate Cancer

Ref. [83] provided guidance on how to handle prostate cancer during the COVID-19 pandemic. The recommendations covered a range of topics, including general factors to consider, diagnostic procedures, different stages of the disease, treatment choices, patient support, and interdisciplinary cooperation. The key objective is to reduce the risk of infection while also preventing unnecessary delays and maintaining treatment efficacy. The article addresses practical concerns arising from the pandemic, such as invasive diagnostic procedures, robotic-assisted laparoscopic prostatectomy, hypofractionated radiotherapy, and prolonged androgen deprivation therapy.

Ref. [84] offered recommendations for the management of prostate cancer patients during the COVID-19 pandemic. The authors collected insights from various centers worldwide, including the United States, Italy, Spain, France, India, Germany, England, Belgium, and Russia, through online webinars and urologic meetings. The article suggests managing prostate cancer patients by modifying office routines, categorizing patients based on their National Comprehensive Cancer Network (NCCN) risk profile, and utilizing COVID-19-based criteria to determine which patients should undergo surgery at the start of the COVID-19 outbreak. These actions are essential for maintaining high-quality treatment and minimizing viral infections among oncological patients. The authors also found Robot-assisted radical prostatectomy (RARP) to be safe and feasible for patients and healthcare workers when taking the necessary precautions.

4.1.12. Thyroid Cancer

According to Ref. [85], patients with thyroid nodules and thyroid cancer referred for diagnostic checks and treatment are not considered at a higher risk of COVID-19 infection compared to the general population. However, the pandemic has still had several significant impacts on their diagnosis and treatment.

Firstly, social isolation, reduced access to investigations, and staff redeployment have resulted in delays in diagnosis. Secondly, treatment planning has had to consider the risk of nosocomial transmission of the virus to patients and staff. Finally, there are concerns about the interaction between the virus, its treatments, and cancer, as highlighted in Ref. [86–89].

4.1.13. Skin Cancer

According to Ref. [90], the impact of skin cancer on the risk of adverse COVID-19 outcomes is presently unknown. Although some studies have indicated higher mortality and hospitalization rates in cancer patients with COVID-19, potentially due to delayed diagnosis and pre-existing comorbidities from chemotherapy and radiation treatments [91], others have suggested that cancer could protect against COVID-19 mortality [92]. The reasons for this are unclear, but it could be due to natural immunosuppression that reduces the adverse effects of a cytokine storm.

Regarding the impact of the COVID-19 pandemic on skin cancer, Ref. [93] reports a significant reduction in skin cancer diagnoses during the pandemic, with a decrease of 68.6 per cent compared to the same period in 2019. Interestingly, waiting times for skin cancer diagnosis were also reduced in the COVID-19 period compared to the pre-COVID-19 period. The main challenge has been balancing the risk of cancer progression with the risk of infectious disease [94].

4.2. Conclusion

In this section, we investigated the impacts of COVID-19 on the most common cancer types listed in Ref. [95]. For cancer patients who require immunotherapy, the work focuses on complications and mortality due to COVID-19. As these patients are more vulnerable to the virus, increased risks of compromised immune systems are an overriding factor for creating treatment plans. For cancer patients requiring hospitalisation or surgery, there are concerns about the risks of COVID-19 to both patients and health workers. A variety of published articles have provided suggestions on whether the

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services should be delayed or carried out as normal. Additionally, surrogate healthcare guidelines for delayed services are discussed.

5. Impact on Patients with End-of-Life/Palliative Care

5.1. Literature Review

The COVID-19 pandemic has resulted in more than three million deaths worldwide and over 900 in Australia [96]. Healthcare providers have been forced to make challenging ethical decisions about prioritizing ICU care and ventilator support for patients with greater chances of survival. As a result, the pandemic has disrupted the end-of-life care of patients, making it more complex and challenging for palliative care providers [97]. Palliative care involves a complex interaction between patients and caregivers, which is more likely to have been affected by the COVID-19 pandemic.

5.2. Pain Management

Chronic pain is a major cause of disability worldwide and is often accompanied by psychiatric comorbidities. Chronic pain has also been linked to the opioid crisis. Access to pain treatment has been recognized as a fundamental human right by many organizations. The COVID-19 pandemic has presented a quandary for doctors who must navigate between the imperative to contain the virus's spread and the need to administer pain relief treatment [98]. The societal impact of chronic pain is significant, as it not only leads to suffering but also impairs daily activities and increases illicit drug consumption, sick leave frequency, disability, and pension payments. These downstream costs create a major problem for public health and place a substantial burden on healthcare systems and disability insurance [99,100].

To assist patients who are facing pain management service shortages or interruptions during the COVID-19 pandemic, a collection of informative articles has been published. These articles provide valuable experience and recommendations. Ref. [101] summarizes the key lessons learned and pain management strategies that were developed at the outset of the pandemic. One key lesson learned was the importance of keeping information transparent and up-to-date while taking swift and decisive action. Other recommendations included quarantine and personal protection measures, as well as telemedicine support for both COVID-19 and non-COVID-19 patients. Regarding pain management strategies, the authors suggested a variety of approaches such as outpatient and inpatient care, telemedicine support, and patient home visits. They also provided special case reports for patients with and without COVID-19.

In Ref. [46], healthcare professionals have been provided with guidance for caring for patients with chronic pain, as well as insights into transitioning to remote care with technology. The authors also explore lessons learned that could benefit the future of pain treatment centers. Four key factors are discussed to guide healthcare professionals in managing patients with chronic pain. Healthcare professionals should consider four factors related to chronic pain patients during the COVID-19 pandemic, which include the public health consequences of COVID-19 for these patients, the risks of not treating them, remote assessment and management options, and the clinical evidence supporting remote therapies.

Ref. [46] examined the impact of the COVID-19 pandemic on chronic pain treatment and provided recommendations for managing chronic pain patients during this time. The recommendations included: (1) following CDC guidelines for infection control in healthcare settings, (2) screening patients and staff for COVID-19 symptoms, (3) triaging pain procedures based on urgency, (4) limiting in-person visits when possible and considering factors such as pain severity and comorbid conditions when making decisions about in-person visits, (5) adapting ongoing therapy to reduce the risk of COVID-19, (6) performing urgent procedures with minimal personnel and avoiding deep sedation, and (7) considering intrathecal pump refills as an emergent procedure, and in some cases, planning for in-home pump refills.

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Ref. [98] proposed a framework that enables pain practitioners and healthcare institutions to manage the competing goals of minimizing risk for healthcare providers and patients, preserving resources, and ensuring access to pain management services. When making a decision about whether to conduct an in-person visit, reschedule to telemedicine, postpone the appointment, or perform a procedure, several factors need to be considered. These factors include the level of urgency, comorbid psychiatric and social considerations, pain levels, potential benefits of the visit or procedure, the risk of the patient seeking emergency services or starting opioids, the necessity of a physical examination, the potential risk associated with an in-person visit or procedure, the patient's job status, and whether they are likely to return to work with proper pain treatment. The first responders and critical personnel, who offer the most significant benefit to society, should be prioritized.

5.3. Palliative Care

The COVID-19 pandemic has emphasized the critical role of palliative care in managing the needs of critically ill and dying patients [102]. The pandemic has caused a surge in demand for managing symptoms, having conversations about serious illness, and addressing dyspnea [103]. In low- and middle-income countries (LMICs), the need for palliative care is even greater due to challenges in healthcare systems, lack of preparedness for outbreaks, shortages of personal protective equipment and medical technology, difficulties in implementing physical distancing measures, and reliance on informal employment [104]. In LMICs, it is expected that patients with severe COVID-19 will not have access to intensive care resources or hospital beds and will pass away at home, with family members caring for them without proper protective equipment or access to palliative care resources. This situation increases the risk of infection transmission [105–107].

Providing palliative care during the pandemic has economic benefits, as it is less costly than usual care and reduces the burden on health systems, which benefits other patients [105,106,108]. In addition, palliative care improves the quality of end-of-life care and dying compared to formal care treatments. Changes in palliative care delivery during the pandemic include the rapid development of telemedicine, changes in regulations to ensure physical distancing and better coordination of palliative care and quarantine orders, and increased involvement of family members in palliative care due to the strain on the healthcare system [109].

Ref. [100] presents a handbook for healthcare professionals and policymakers on the difficulties that pandemics or disasters pose to healthcare provision, particularly in the area of palliative care. The paper outlines the crucial function that palliative care serves in assisting patients during the COVID-19 pandemic, including the importance of planning for end-of-life care and the ethical dilemmas related to decision-making on the allocation and rationing of resources. Furthermore, the paper delineates the fundamental principles that govern the allocation of limited resources and the pragmatic considerations involved in putting these principles into practice. The authors urge governments at all levels to work alongside clinicians and communities to spearhead the creation of clear and transparent protocols for formulating decision-making guidelines in times of pandemics or disasters. The article underscores the significance of governments acknowledging their legal and ethical accountability for formulating guidelines that entail challenging decisions regarding the denial of treatment when resources are insufficient during a significant disaster, severe epidemic, or pandemic like COVID-19.

Numerous studies have examined various aspects of end-of-life care, symptom management, and supportive therapies in COVID-19 patients. Ref. [110] represents one of the earliest and largest Australian reports on the end-of-life experiences and symptomatology of patients who died from COVID-19 in a large Victorian tertiary hospital. The findings of this study can aid clinicians in anticipating the palliative care needs of COVID-19 patients, such as using higher starting doses of opioids and sedatives to mitigate breathlessness and agitation near death. Ref. [111] undertook a case series of 101 patients referred for hospital palliative care in the UK and analyzed their symptom burden, management, responses to treatment, and outcomes.

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Ref. [112] investigated how the COVID-19 pandemic has affected the experiences of next-of-kin and carers who witnessed the death of their loved ones in residential aged care facilities (RACFs). The study revealed that participants and their dying loved ones faced various pandemic-related challenges in RACFs. It is vital for dying residents and their families to have access to palliative care and bereavement support, but the pandemic has made it more challenging to obtain these resources.

Ref. [113] proposed a unique approach to facilitate patient and family care during the COVID-19 pandemic by utilizing nursing and social work strategies to overcome social distancing and visitation limitations. The article provides an introduction to the interdisciplinary palliative medicine team and the humanistic interventions used to establish trust, connection, and hope with patients and families. Additionally, the article presents a qualitative synthesis of the team's journal reflections on the challenges faced in providing patient and family care during COVID-19. It also examines the patients' and families' responses to the team's humanistic interventions and discusses the personal and professional experiences of the team members during the pandemic.

Ref. [114] provided information to help Australians understand and create advance care planning during the COVID-19 pandemic. Ref. [115] described the challenges faced by UK specialist palliative care services in regards to advance care planning during the pandemic and the adaptations made to facilitate timely discussions. The authors recommend that healthcare professionals should personalize advance care planning to each individual's values, priorities, and ethnic/cultural/religious backgrounds. Policymakers must consider how to resource high-quality advance care planning as part of routine healthcare to prepare for future pandemic waves, and questions must be raised for consideration at each level of the social-ecological model.

5.4. Conclusion

This section explores the effects of COVID-19 on pain management and palliative care. The management of chronic pain has become increasingly difficult during the COVID-19 pandemic, particularly due to mounting evidence linking COVID-19 infection to myalgias, referred pain, and widespread hyperalgesia [116]. Palliative care, which involves the early identification, impeccable assessment, and treatment of pain and other physical, psychosocial, and spiritual issues to improve the quality of life of patients and their families facing life-limiting illnesses, has become more crucial yet challenging under the COVID-19 pandemic as healthcare systems are overwhelmed [100,117]. Providing safe and effective palliative care, including end-of-life care, has become especially vital during this time.

6. Analysis Methodology

To analyse the impact of the COVID-19 pandemic on chronic diseases and cancers, the analysis team followed the steps outlined below:

- identifying analysis questions
- preparing and pre-processing available data sets
- conducting analysis

6.0.1. Identify Analysis Questions

Key analytic questions are outlined below:

- identifying change categories (e.g., dispensing patterns for drugs, surgery, radiotherapy, hospitalisations, and use of telehealth), which were the initial input features for conducting the analysis, compared with those cohorts without COVID-19
- identifying health outcomes for chronic diseases (e.g., death, complications/adverse events, disease progression, and healthcare service pathways), which were considered the targets of the analysis

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- identifying health outcomes for cancers (e.g. prescribing of anti-depressants, changes in chronic disease management plans for cancer patients, shifts in palliative care from hospital to home, remoteness, access to specialists, uptake of diagnostic testing and monitoring, hospitalisations, complications/adverse events and death)
- analysing correlations between changes and outcomes.

Table 1. Typical chronic diseases and cancer - code mapping.

Diseases	Anatomical Therapeutic Chemical (ATC) Classification	International Classification of Diseases (ICD)-10
Diabetes	A10	E10 - E14
Kidney Disease	B03XA01, B03XA02, B03XA03, B03AE02, B03AE03, B03AE05	N18
Poorly Controlled Blood Pressure	C02, C03AA, C07, C08, C09	I10, R03
HIV	J05AE, J05AR, J05AF, J05AG, J05AX07, J05AX09, J05AJ	B20 - B24
Hepatitis	J07CA09, J07CA11, J07CA13, J07CA05, J07CA07, J07CA12, J07CA08, J06BB11, J07BC02, J06BB04, J07BC01, J07CA10	B15 - B19
Osteoporosis		M80 - M82
Cancer	L01	C81-C96,D693,Z511,Z510

6.0.2. Data Pre-Processing

The health care activities of people with chronic conditions mainly consisted of prescriptions, visiting doctors [118], and hospitalisation (ICD-10). Key data pre-processing steps are outlined below:

- the linkage between those available datasets was the first step in conducting analysis in this task
- extracting data of people with typical chronic diseases (e.g. diabetes, kidney disease, poorly controlled blood Pressure, HIV, hepatitis, and osteoporosis) from the linked data
- extracting data of people with cancer and processing each individual's data according to a sequence of activities with timestamps
- generating disease-code mapping (Table 1).

6.0.3. Data Analysis on Typical Chronic Diseases and Cancer

Key data analytic activities are outlined below:

- statistical analysis on patient cohorts, such as certain demographics, diagnosis profiles or health care utilisation patterns and health outcomes
- analysing how health and social outcomes and the utilisation of reproductive health and fertility services have changed during COVID-19
- analysing the impact on specialist clinics that provide services for patients with chronic conditions
- analysing correlations between learned patient pathways and outcomes
- analysing risk factors for poor health outcomes before and after the COVID-19 pandemic

7. Conclusions

This paper reviewed literature from academic research journals and government health organization reports conducted on how COVID-19 impacted patients with complex health conditions. We investigated COVID-19 impact on three vulnerable cohorts ategorised in this review, such as

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patients with chronic disease, patients with cancer, and patients with end-of-life care. Analysis methodology and typical chronic diseases and cancer-code mapping table were proposed in this paper to identify each cohort from an analytics perspective. The paper presents a comprehensive literature review on the COVID-19 impact on patients with health conditions. This paper provided evidence on how to improve the quality of life for vulnerable populations and to inform a national response strategy for future pandemics, which seems inevitable in a highly globalised economy.

The paper presents a comprehensive literature review on the COVID-19 impact on patients with health conditions. Data-driven analysis of the impact of the pandemic on patients with complex health conditions helps governments change national response strategies according to real-world impacts. The actionable knowledge and management discovered by this literature review can support clinical actions and decision-making aid for diagnosis and treatment of diseases in real environments. The proposed analysis methodology and typical chronic diseases and cancer-code mapping table can be implemented into the health care domain to improve decision-making.

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