# Impact of pandemic (H1N1) 2009 influenza on critical care capacity in Victoria

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## ABSTRACT

**Objective:** To describe the demand for critical care hospital admissions in Victoria resulting from the rapid rise in the number of pandemic (H1N1) 2009 influenza cases, and to describe the role of modelling tools to assist with the response to the pandemic.

**Design and setting:** Prospective modelling with the tools FluSurge 2.0 and FluAid 2.0 (developed by the United States Centers for Disease Control and Prevention) over 12 weeks from when the pandemic "Contain" Phase was declared on 22 May 2009, compared with data obtained from daily hospital reports of pandemic (H1N1) 2009 influenza-related admissions and transfers to intensive care units (ICUs).

**Main outcome measures:** The effect on hospitals as projected by the FluAid 2.0 model compared with observed hospital admissions and ICU admissions.

**Results:** Prospective use of the FluAid 2.0 model provided valuable health intelligence for assessment and projection of hospitalisation and critical care demand through the first 10 weeks of the pandemic in Victoria. The observed rate of hospital admissions for pandemic (H1N1) 2009 was broadly consistent with a 5% gross clinical attack rate, with 0.3% of infected patients being hospitalised. Transfers to ICUs occurred at a rate of 20% of hospital admissions, and were associated with vulnerable patient groups, and severe respiratory failure in 82% of patients admitted to ICUs. Most patients treated in ICUs (85%) survived after an average ICU length of stay of 9 days (SD, 6.5 days). Mechanical ventilation was required by 72% of patients admitted to ICUs, and extracorporeal membrane oxygenation (ECMO) was used for 7%. Pre-existing haematological malignancy accounted for half of all the deaths in patients admitted to ICUs with pandemic (H1N1) 2009 influenza.

**Conclusions:** Prospective use of modelling tools informed critical decisions in the planning and management of the pandemic. Early estimation of the clinical attack rate, hospitalisation rates, and demand for ICU beds guided implementation of surge capacity. ECMO emerged as an important treatment modality for pandemic (H1N1) 2009 influenza, and will be an important consideration for future pandemic planning.


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Following the emergence of the novel H1N1 influenza 09 (human swine flu), global surveillance of the spread and epidemiology of this virus has been high. The establishment of local infection was recognised in Victoria in late May, which coincided with the beginning of the winter seasonal influenza period, and prompted the shift in Australian pandemic phases from the "Delay" Phase to the "Contain" Phase on 22 May 2009.[1] Intensive public health measures to identify and confirm all cases of pandemic (H1N1) 2009 influenza during this phase provided baseline data to inform the ongoing assessment of the impact of the pandemic on the acute care health system.

A review of available data sources for influenza surveillance in Victoria had previously identified that existing mechanisms for surveillance through hospitals would not be sufficiently timely for operational purposes during a pandemic.[2] Before the commencement of the Contain Phase, three parameters were identified for daily reporting by hospitals to the Victorian Health Emergency Coordination (VHEC) of the Victorian Department of Human Services (DHS). These were: (i) the number of emergency department presentations compared with usual daily demand; (ii) hospitalisation of patients with laboratory-confirmed H1N1 infection; and (iii) transfer to an intensive care unit (ICU) of patients with confirmed H1N1 infection. A secure website was established for daily hospital reporting. These data were used for prospective forecasting and assessment of the impact of the H1N1 pandemic on hospitals using modelling tools.

On 3 June 2009, the pandemic phase was changed to "Modified Sustain", with the recognition that sustained community transmission was occurring in Victoria.[3] Community diversion influenza clinics were established to mitigate high volumes of presentations to emergency departments and hospitals. The World Health Organization declared a global pandemic on 11 June 2009, and Australia moved to a "Protect" Phase on 23 June, which shifted the focus to testing, treatment and prophylaxis for vulnerable groups.[4] This phase reduced the requirements for laboratory testing at the community level, but hospitalised patients continued to receive intensive surveillance.

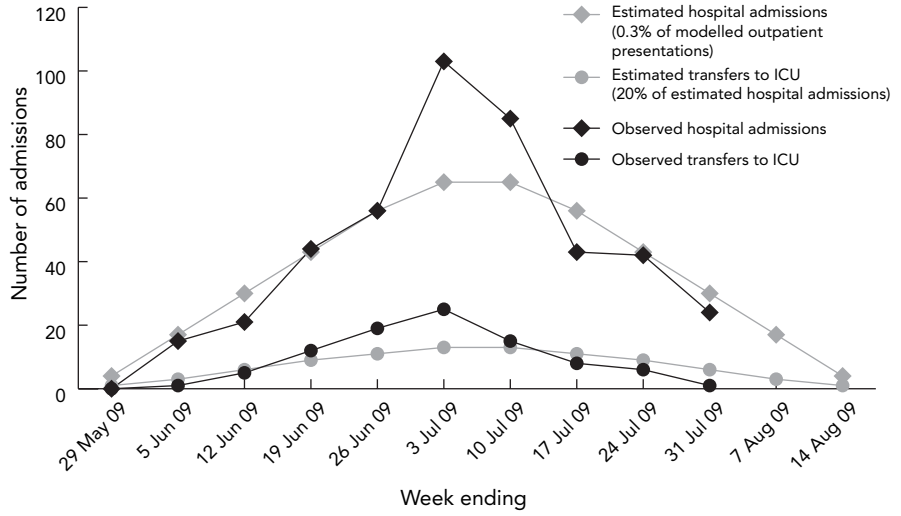
As Victoria was the first Australian jurisdiction to experience the rapid rise in the number of pandemic (H1N1) 2009 influenza cases, we describe the critical care hospitalisations of all patients admitted to Victorian hospitals with laboratory-confirmed pandemic (H1N1) 2009 influenza infection, and the role of modelling tools in assisting with the response to the pandemic.

## METHODS

Laboratory-confirmed influenza is a notifiable disease under the *Health (Infectious Diseases) Regulations 2001* (Vic). Hospital demand volumes were compared with notifications to the Notifiable Infectious Disease Surveillance (NIDS) database maintained by the DHS. ICU admissions were verified through daily contact between the DHS and each hospital ICU.

Forecasting and assessment of the impact of the H1N1 influenza 2009 pandemic on hospitals was achieved through use of the two modelling tools; FluSurge 2.0 and FluAid 2.0, developed by the United States Centers for Disease Control and Prevention (CDC).[5] FluSurge estimates the surge in demand over time for hospital-based services, whereas FluAid provides a range of estimates of impact in terms of deaths, hospital admissions, and outpatient presentations due to pandemic influenza. As inputs into the FluAid 2.0 model, we used the default FluAid 2.0 estimates of outpatient presentations per 1000 population. These were US national estimates of outpatient presentation rates from influenza per

**1 Observed weekly numbers of pandemic (H1N1) 2009 influenza-related hospital admissions and intensive care unit (ICU) transfers in Victoria, compared with estimated weekly numbers based on a 5% clinical attack rate, and a 0.3% hospital admission rate**




1000 population by age and risk group, based on the definition of groups at high risk for complications of influenza infection as determined by the CDC's Advisory Committee on Immunization Practices (ACIP).[6,7] These high-risk groups are:

- People aged 65 years or older;
- Residents of nursing homes or other chronic care facilities that house people with chronic medical conditions;
- Adults and children who have chronic disorders of the pulmonary or cardiovascular systems, including those with asthma;
- Adults and children who require regular medical follow-up or hospital admission because of chronic metabolic diseases (including diabetes mellitus), renal dysfunction, haemoglobinopathies, or immunosuppression (including immunosuppression caused by medications);
- Children and teenagers (aged 6 months to 18 years) receiving long-term aspirin therapy, and who might therefore be at risk of Reye syndrome after influenza infection; and
- Women who will be in the second or third trimester of pregnancy during the influenza season.

A gross clinical attack rate is the percentage of the population who become clinically ill from influenza, with clinical illness being defined as a case of influenza that causes some measurable economic impact, such as a half day of work lost, or a visit to a physician's office. We chose gross attack rates to create three "scenarios" of impact:

- 5% for minimum (or "best-case" scenario), which estimates the fewest possible number of outpatient presentations;
- 10% for mean (or "most likely" scenario), which estimates the number of outpatient presentations most likely to occur; and
- 20% for maximum (or "worst-case" scenario), which estimates the largest number of outpatient presentations.

Based on an estimated resident population of 5 381 148 in Victoria in 2009, FluAid 2.0 estimated 143 740, 287 479 and 574 959 outpatient presentations for 5%, 10% and 20% gross clinical attack rates, respectively. In the Victorian context, outpatient presentations were defined as presentations to general practitioners, emergency departments or influenza clinics. General practice data available from 87 sentinel practices provided evidence of clinical disease in the community, and an approximation of presentation rates. Prior to the Contain Phase, there had been no hospital admissions for pandemic (H1N1) 2009 influenza infection in Victoria, and therefore no patient data to populate the model. There was also no certainty as to which assumptions within the model parameters would be the most appropriate. We used real-time data for actual cases to inform the modelling, and to identify a best-fit curve. Early data supported the use of a model for projection of cases distributed over 12 weeks using the distribution from the FluSurge 2.0 model.

Hospital admission numbers were modelled over 12 weeks as being between 0.1% and 0.5% (in 0.1% increments) of estimated outpatient presentations during this period. Transfers to ICUs were modelled as 20% of hospital admissions (Box 1). Data from daily hospital reports were applied to the model to assist with health service planning by the VHEC. Estimated hospital presentations from the FluAid 2.0 model, using 5%, 10% and 20% clinical attack rates, were compared with the observed hospital presentations. Additional data from specially established community diversion influenza clinics contributed to monitoring and modelling of the hospital impact.

## RESULTS

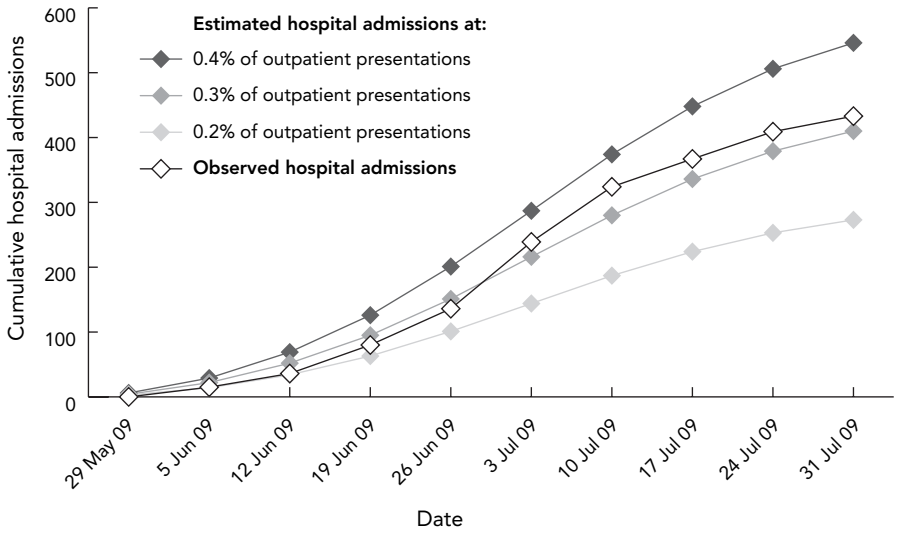
Although the clinical attack rate was unknown at the outset of the pandemic, the Contain Phase provided comprehensive data for hospital presentations and laboratory confirmed cases of pandemic (H1N1) 2009 influenza. The observed number of hospital admissions for H1N1 infection (433 on 31 July 2009) was broadly consistent with the estimate from the FluAid 2.0 model for a 5% gross clinical attack rate, with an estimated 143 740 outpatient presentations, and 0.3% of these being hospitalised (410 on 31 July 2009) (Box 2).

Although there was a 30% excess demand at emergency departments during the Contain Phase, use of the community diversion influenza clinics declined over the subsequent 3 weeks, and emergency department presentations returned to the seasonally adjusted baseline.

With the move to the Protect Phase on 23 June, data from the FluAid 2.0 model placed the observed hospital demand in Victoria at Week 5 of the pandemic, and forecast a further 2–3 weeks before peak demand would be evident. At that time, the number of hospital admissions and ICU transfers for confirmed cases of pandemic (H1N1) 2009 influenza continued to rise, but emergency department presentations remained at seasonal norms.

Before the Protect Phase, the VHEC initiated an ICU Surge Implementation Plan to increase capacity for patients requiring critical care. Additional ICU beds and the release of Victorian pandemic ventilator stockpiles were progressively implemented. VHEC and public health emergency operations were integrated at the DHS Emergency Coordination Centre to maximise the coordination of the government health response, and to enable a consistent but agile approach in ensuring that the community was informed during an uncertain and rapidly changing health emergency.

**2 Observed cumulative number of hospital admissions, compared with projected admission numbers based on 0.2%, 0.3% and 0.4% of estimated outpatient presentations**




While the epidemiological profile of community infection in Victoria describes a relatively young age group susceptible to H1N1 infection (median age, 21 years),[8] the 92 patients with severe disease and who were admitted to an ICU were older (median age, 37 years). These patients reflected the vulnerable population with pre-existing medical conditions and risk factors (Box 3). Due to the elevated risk of serious infection during pregnancy, a bimodal age distribution was observed, with peak incidence occurring in the 20–29-years and 50–59-years age groups (Box 4). Sex differences were only apparent in the 20–29-years age group where the excess proportion of women was the result of the pregnant cohort.

The 10th week of the pandemic in Victoria (FluAid 2.0 model, week ending 29 July) showed a postpeak decline in presentations. The cumulative total for hospital admissions numbered 433 patients, of whom 92 (21%) had been treated in an ICU. This rate of hospital-based care was consistent with the modelled 5% clinical attack rate among the general population, suggesting a stable and relatively mild virulence. Notwithstanding that H1N1 influenza was a mild disease for most of the community, severe disease among vulnerable populations confirmed the early initial observations highlighting the risk of life-threatening respiratory failure.[9] Fewer than 10% of patients requiring intensive care management had no identified risk factor (Box 3).

**3 Main predisposing risk factor in the 92 patients admitted to an intensive care unit**

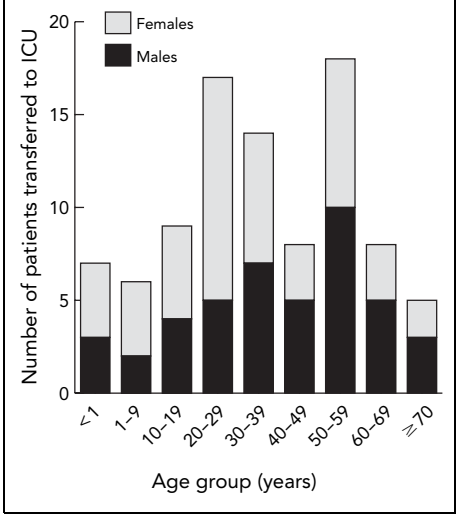
| Risk factor | No. (%) |
|---|---|
| Chronic respiratory disease (asthma, chronic obstructive pulmonary disease, bronchiectasis, lung surgery) | 21 (23%) |
| Immunosuppression (haematological malignancies, immunosuppressant therapy) | 15 (16%) |
| Pregnancy (average gestation, 30 weeks) No risk factor present other than pregnancy (seven women) | 12 (13%) |
| Obesity (moderate to morbid) | 12 (13%) |
| Chronic cardiovascular disease | 11 (12%) |
| Diabetes | 5 (5%) |
| Indigenous background | 2 (2%) |
| Other risk factors | 7 (8%) |
| No identified risk factor | 7 (8%) |

Severe respiratory failure was evident in 82% of ICU admissions, and was caused by moderate to severe pneumonitis, pneumonia and acute respiratory distress syndrome. Mechanical ventilation was required in 72% of ICU admissions, for a mean duration of 9 days (SD, 6.2 days). Maximal ventilation was frequently necessary, including institution of recruitment ventilatory manoeuvres, nitric oxide and, for 7% of cases, extracorporeal membrane oxygenation (ECMO). ECMO has emerged as an important treatment modality for pandemic (H1N1) 2009 influenza.

Most patients with cases of H1N1 infection who were treated in an ICU survived (85%), after an average of ICU length of stay of 9 days (SD, 6.5 days). Of the pregnant women with H1N1 infection who were transferred to an ICU, 67% proceeded to delivery by emergency Caesarean section. There were no cases of maternal–fetal transmission, but two neonatal deaths were reported among mothers with confirmed H1N1 infection who were transferred to an ICU; it was unlikely that one of these could have been directly attributed to H1N1 infection. Severe H1N1 infection was predominantly a single organ (respiratory) disease affecting 68% of patients with H1N1 infection who were transferred to an ICU.

All 14 deaths from H1N1 infection that occurred in hospitals were among vulnerable patients with a recognised risk factor. Pre-existing haematological malignancy accounted for 50% of the deaths, and this suggests an especially susceptible subpopulation of at-risk patients. Two deaths

**4 Patients with pandemic (H1N1) 2009 influenza transferred to an intensive care unit (ICU), by age group and sex**



occurred in patients for whom invasive respiratory support was not offered, in line with their palliative care. One patient presented after sudden cardiac arrest, and was diagnosed with brain death in the ICU before proceeding to organ donation. One mother died postpartum. Half of the patients who died developed multiorgan failure before death.

Of the 92 patients admitted to an ICU, 6.5% were treated for conditions unrelated to H1N1 pathogenesis, or had H1N1 infection that was mild and incidental to their pre-existing disease.

## DISCUSSION

Victoria was one of the first southern hemisphere jurisdictions to experience the emergence of pandemic (H1N1) 2009 influenza in its community. Monitoring and surveillance of the impact on Victorian hospital-based services, in particular the critical care system, provides valuable health intelligence as the pandemic progresses in Australia and in other regions. Dynamic application of observed hospital admissions and ICU admissions to the projected effects on hospitals informed critical decisions in the management of this health emergency. Early estimation of the clinical attack rate, hospitalisation rates, and demand for ICU beds guided implementation of surge capacity across the Victorian health system. The prospective use of the pandemic models to assist in planning was valuable.

The clinical attack rate refers to the number of people infected with pandemic (H1N1) 2009 influenza who needed any form of clinical assessment or care. The 5% clinical attack rate observed in Victoria is well below the level assumed in the Australian Health Management Plan for Pandemic Influenza.[10] This reflects the mild nature of the disease at present. The community attack rate is likely to have been much higher, with most cases being subclinical or minimally symptomatic. Evidence from a serological survey to determine the community attack rates will be needed as soon as is practicable. The estimates of the number of cases presenting for care are broadly consistent with the experience of general practitioners and influenza clinics, but the lack of clinical reporting from primary care, beyond sentinel surveillance in Australia, is an obstacle that needs to be removed to improve health intelligence objectives. Epidemiology of the outbreak in the community from the sentinel surveillance scheme and other sources will be described elsewhere.

Implementation of community-based diversion clinics for influenza was consistent with the observed low clinical attack rate and moderate virulence. Detailed analysis of influenza clinic performance will also be described elsewhere. Peak demand in emergency department presentations was relatively brief in areas where diversion clinics were operating. These clinics progressively closed once demand declined, and were no longer required by the end of the 6th week (week ending 3 July). Monitoring of ICU demand through the VHEC function of the DHS provided the capacity for system-wide response and rational distribution of resources, and helped critical care clinicians communicate and share experiences as the pandemic unfolded.[11]

Laboratory notifications of pandemic (H1N1) 2009 influenza exceeded normal seasonal rates of laboratory-confirmed influenza notifications, but the bias introduced by increased testing limits the usefulness of these notifications. However, despite the relatively moderate virulence, the impact on hospital services was most evident in the provision of isolation facilities and ICU capacity. A hospitalisation rate of 0.3% and an ICU transfer rate of 20% of hospitalised patients were initially observed, although these rates varied during the course of the pandemic. The severity of respiratory illness among the vulnerable population produced a surge in ICU admissions with high demand for ventilation support, and with patients requiring a relatively long duration of intensive care before recovery. The peak demand was exacerbated by the compounding number of patients in ICU. The speed with which the pandemic affected critical care services required reporting and data systems that were more responsive than normal operational systems. Laboratory-confirmed influenza is classified as a Group B notifiable disease, which means that cases must be notified in writing by both medical practitioners and laboratories within 5 days of confirmation. Through the peak of the pandemic, daily demand data were essential to adequately inform tactical and strategic decisions, and classifying pandemic influenza as a Group A notifiable disease with immediate notification should be considered. Data management systems to facilitate rapid notification, while minimising the reporting burden, and maintaining high levels of data quality, will need to be implemented to support the response to large-scale health emergencies.

Our findings describe the first 10 weeks of the pandemic (H1N1) 2009 influenza outbreak in Victoria, from the commencement of the Contain Phase, when established community spread was first identified. Hospital admissions and ICU admissions for pandemic (H1N1) 2009 influenza continue in Victoria, and the dynamic and, in some instances, interim characteristics of available data are a limitation of this report. Further reporting of the clinical management and outcomes from hospital admission and ICU admission will follow. The impact on critical care capacity, particularly as a result of the demand for ECMO therapy, will be an important consideration for future planning. Although the pandemic (H1N1) 2009 influenza presentations in Victoria appear to be in the post-peak phase, continued surveillance of the ICU system remains important to detect any shift in virulence, the occurrence of a subsequent wave of infection, and to observe whether seasonal influenza subtypes cause severe disease along with other winter pathogens. The experience from this novel pandemic influenza will provide important information for future emergency preparedness affecting the critical care systems in Victorian hospitals.

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## COMPETING INTERESTS

None identified.

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