中文摘要

本研究之目的在於發展一室內呼吸性疾病之控制策略模式，進而加以量化公共衛生之風險。此控制策略模式主要以函數之相關性整合四種流行病學之方程式，分別為修正之Wells-Riley數學模式、競爭-風險(competing-risks)模式、Von Foerster方程式以及典型的受體-感染-復原(Susceptible-Infectious-Recovered, SIR)模式。本研究中所利用之控制策略則是結合工程控制方法包含增加通風量、增加通風設備之過濾系統、紫外線殺菌(UVGI)系統和個人用之口罩以及政策控制干預包括隔離、疫苗、接觸追蹤以及洗手，用以建構一方便使用以及簡易說明之臨界控制線。並應用上述之數學方法針對流行性感冒、水痘、麻疹以及嚴重急性呼吸性症候群(SARS)四種先前曾爆發過之呼吸性疾病，提供最佳之控制策略。本研究估計SARS在醫院中之傳輸，其平均一個病人在一個室內之空間當中可以傳染 2.7 個新病例，針對流行性感冒、水痘和麻疹而言，則是計算這三種呼吸性疾病位於商用飛機上之擴散，在一次旅途中所產生基本再生數(R_0)之估計值分別為 11.7、15.1 和 6.0。接著本研究利用增加工程控制方法以降低傳染性疾病之R_0 值，計算結果成功降低四種疾病之R_0 值，流行性感冒降低為 2.0、水痘降低為 0.6、麻疹降低為 4.4 則SARS可降為 0.3；其後本研究模擬政策干預之加入，模擬顯示政策干預可明顯地降低四種室內呼吸性傳染疾病之爆發風險。最後，由本研究之結果指出結合工程控制方法及政策干預可以有效地控制流行性感冒和水痘的爆發；另一方面針對SARS而言，只要使用高效率隔離已產生症狀之病人，加上使用低效率之接觸追蹤即可有效地控制疾病之爆發。本研究建議有系統地量化傳染性疾病之傳輸性及考慮無症狀但具有傳染性期間之比例可有效為評估室內呼吸性傳染疾病控制方法之選擇。

關鍵字:室內呼吸性傳染疾病；基本有效再生數(R_0) ；數學模式；室內空氣品質；控制策略；風險

Abstract

The purpose of this study is to quantify the public health risk and to develop control measure modeling approaches concerning in containing indoor respiratory infections. Here we integrate four different types functional relationship of modified Wells-Riley mathematical model, competing-risks model, Von Foerster equation, and standard susceptible-infectious-recovered (SIR) model to construct easy-to-use and easy-to-interpret critical control lines. We examine mathematically the impact of engineering control measures such as enhanced air exchange, ventilation filter, ultraviolet germicidal irradiation (UVGI) system and personal mask combined with administrative interventions such as vaccine, isolation, contact tracing and handwashing in containing the spread of indoor respiratory infections. We demonstrate the approach with example of optimal control measures to priority respiratory infections of severe acute respiratory syndrome (SARS), influenza, measles and chickenpox. We estimate that a single case of SARS will infect 2.7 secondary cases on average in a population from nosocomial transmission. We also obtain an estimate of the basic reproduction number (R_0) for influenza, measles, and chickenpox in a commercial airliner: the median value is 11.7, 15.1, and 6.0 respectively. If enhanced engineering controls could reduce the R_0 below 2.0 for influenza, 4.4 for measles, 0.6 for chickenpox and 0.3 for SARS, our simulations show that in such a prepared response with administrative interventions would have a high probability of containing the indoor respiratory infections. Our analysis indicates that combinations of engineering control measures and administrative interventions could effective contain influenza and chickenpox; on the other hand effective isolation of symptomatic patients with low-efficacy contact tracing is sufficient to control a SARS outbreak. We suggest that a valuable added dimension to public health interventions could be provided by systematically quantifying transmissibility and proportion of asymptomatic infection of indoor respiratory infection.

Key words: Indoor respiratory infection; Basic reproduction number; Mathematical models; Indoor air quality; Control measure; Risk