PUBLIC POLICY RESEARCH FUNDING SCHEME

公共政策研究資助計劃

Project Number :
項目編號： 2015.A4.008.15C

Project Title :
項目名稱： Designing a Sustainable Public-Private-Partnership Program to Enhance Diabetes Care and Evaluating Its Impact Using an Outcomes Simulation Model
設計一項可持續的糖尿病護理公私營協作計劃及利用電腦模擬系統預測其成效

Principal Investigator :
首席研究員： Professor CHAN Chung Ngor Juliana
陳重娥教授

Institution/Think Tank :
院校／智庫： The Chinese University of Hong Kong
香港中文大學

Project Duration (Month):
推行期 (月)： 15

Funding (HK$) :
總金額 (HK$)： 552,000.00

DESIGNING A SUSTAINABLE PUBLIC-PRIVATE-PARTNERSHIP PROGRAM TO ENHANCE DIABETES CARE AND EVALUATING ITS IMPACT USING AN OUTCOMES SIMULATION MODEL

設計一項可持續的糖尿病護理公私營協作計劃
及利用電腦模擬系統預測其成效

PRINCIPAL INVESTIGATOR
Professor Juliana CN Chan

CO-INVESTIGATORS
Dr. Shek Ng
Professor Andrea Luk
Dr. Wingyee So
Professor Benny Zee

Hong Kong Institute of Diabetes and Obesity
Department of Medicine and Therapeutics
Jockey Club School of Public Health and Primary Chare
The Chinese University of Hong Kong
Prince of Wales Hospital
Hong Kong

ANALYST
Mr. Eric Lau

Asia Diabetes Foundation
The Chinese University of Hong Kong
Hong Kong

CONSULTANT
Professor Philip Clarke

Melbourne University
Australia

14th February 2017

SPECIAL ACKNOWLEGEMENTS

We thank all health care professionals, researchers and supporting personnel at the Chinese University of Hong Kong, Prince of Wales Hospital, Alice Ho Nethersole Hospital, Asia Diabetes Foundation, Hospital Authority, sponsors and donors for their invaluable contribution to the establishment of the Hong Kong Diabetes Registry (HKDR) which have provided the foundation for the Joint Asia Diabetes Evaluation (JADE) Program.

We are most grateful to all patients who have kindly agreed to contribute their anoymous data and support our ongoing research in pursuit of prevention and control of diabetes and its complications.

The analysis of this quality improvement program was funded by the Hong Kong Government Public Policy Research Funding Scheme (2015.A4.008.15C). The implementation and evaluation of the the JADE Program was approved by the Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee.

DECLARATION OF INTEREST

Professor Juliana Chan is the principal investigator who conceptualized, designed, implemented and evaluated the HKDR, JADE Program and Chinese Diabetes Outcome Model. She is the Chief Executive Officer, on a pro-bono basis of the Asia Diabetes Foundation, a charitable organization registered in Hong Kong governed by the Chinese University of Hong Kong Foundation. She is also the Director of the Yao Chung Kit Diabetes Assessment Centre of the Hong Kong Institute of Diabetes and Obesity, The Chinese University of Hong Kong, Prince of Wales Hospital.

Executive summary

1. Objectives

1.1. To propose a sustainable private public partnership (PPP) scheme to promote community-based diabetes integrated care programme with quality assurance and ongoing evaluation.

1.2. To project the effect of the PPP scheme within 20 years in terms of reducing the number of diabetic patients developing retinopathy, cardiovascular-renal and cancer events, using a probabilistic outcomes simulation model.

1.3. To perform budget impact analysis for implementing the proposed PPP scheme.

2. Private-public imbalance in provision of diabetes care

2.1. In 2015, with an annual income of HKD 55,230 million, the Hong Kong Hospital Authority (HA) provided over 90% of inpatient care and 70% of outpatient care, the latter being mainly associated with chronic disease including diabetes. While quality diabetes care can save life and money, its effective implementation requires a stable doctor-patient relationship, patient education, long term medications and regular monitoring. Based on the latest estimates, 600,000 adults in Hong Kong have diabetes with 70% (~400,000) of them being followed up in the HA setting.

2.2. In 2015, HA employed 45% (n=5,884) of all registered doctors (n=12,981) but managed 90% of patients diagnosed with diabetes. Amongst many reasons, huge differences in drug acquisition costs, fee-for-service, lack of support for comprehensive assessment and patient education outside the HA setting, which are often time- and labour-intensive, have excluded many private doctors from providing quality diabetes care despite their experiences, expertise and commitment.

3. Integrated diabetes care using PPP

3.1. In 1995, The Chinese University of Hong Kong (CUHK) established the Hong Kong Diabetes Registry (HKDR) and reported the young age of diagnosis (~ 50 years) with 50% of patients suffering from a critical illness (heart disease, stroke, cancer and/or renal failure) including premature death after 10 years of diabetes, i.e. at the age of 60. Yet, by using a stable doctor-nurse team to implement an evidence-based care program with pre-specified clinical procedures and treatment targets together with regular feedback to doctors and patients, we could reduce the risk of critical illnesses including death by 50-70%.

3.2. In 2007, supported by an educational grant, we established the Asia Diabetes Foundation (www.adf.org.hk), governed by the CUHK

Foundation to develop the innovative, web-based Joint Asia Diabetes Evaluation (JADE) Program which integrates evidence-based care protocol, validated risk engine, personalized reporting and decision support to enable patients and doctors make shared and informed decisions and create the JADE Registry for quality improvement.

3.3. Apart from the Prince of Wales Hospital (PWH) which adopted the JADE Program, in 2007, supported by a donation, the CUHK established the nurse-led Yao Chung Kit (YCK) Diabetes Assessment Centre (http://www.yckdac.hkido.cuhk.edu.hk/en/index.html) under the Hong Kong Institute of Diabetes and Obesity to provide yearly JADE-guided comprehensive assessment and empowerment programs to patients on self- or doctor-referred basis to improve diabetes care through PPP.

4. Chinese Diabetes Outcome Model and effects of PPP

4.1. Between 2007 and 2015, patients with diabetes attending the PWH Diabetes Centre (HA-JADE: n=9,676) and YCK Centre (PPP-JADE: n=3,570) had 20-50% lower hospitalization rates than patients receiving standard care in a typical public hospital (HA: n=3,424).

4.2. Using clinical and laboratory data from 9,506 patients with type 2 diabetes registered in the HKDR observed between 1995 and 2007, we developed the Chinese Diabetes Outcome Model (CDOM) to quantify interactions between demographic profiles, risk factors and complications to predict the probabilities of multiple critical illnesses till occurrence of death over a 15-year period. These predicted rates were similar to the observed rates supporting the validity of the CDOM.

4.3. We applied the CDOM to simulate the clinical outcomes in 400,000 patients with diabetes with profiles similar to those attending HA clinics and projected that implementation of the PPP-JADE model could reduce cardiovascular-renal disease and death by 11-77% over a 15-year period.

5. Economic analysis of implementing PPP

5.1. Based on an estimated population of 400,000 adults with diabetes managed in HA setting, implementation of the JADE Program in the public setting can save a HA expenditure of HKD 750,519,537 (HKD 1,876 /patient/year) which represents 1.35% of HA annual income.

5.2. If we implement the JADE model with follow up by a stable doctor-nurse team through a community-based Diabetes Centre through PPP, the HA can save an expenditure of HKD 3,253,126,108 (HKD 8,133 /patient/year) which represents 6% of the annual HA income.

	Risk level	Hospital night/year	% of 400,000 HA patients	Estimated no of patients	Estimated HA cost per year (HKD4330/night)	HA saving with JADE care in 400,000 patients	Saving per patient per year
HA	1-2	1.572	11.76%	47,036	320,162,763		
HA-JADE	1-2	1.233	11.76%	47,036	251,120,030	-69,042,733	-1,468
PPP-JADE	1-2	0.386	11.76%	47,036	78,615,030	-241,547,734	-5,135
HA	3	3.492	66.22%	264,891	4,005,247,281		
HA-JADE	3	2.970	66.22%	264,891	3,406,524,749	-598,722,532	-2,260
PPP-JADE	3	1.785	66.22%	264,891	2,047,355,784	-1,957,891,497	-7,391
HA	4	7.673	22.02%	88,073	2,926,145,279		
HA-JADE	4	7.456	22.02%	88,073	2,843,391,007	-82,754,272	-939
PPP-JADE	4	4.910	22.02%	88,073	1,872,458,402	-1,053,686,877	-11,964

Very high risk level (4): established cardiovascular disease and end stage renal disease; High risk level (3): ≥3 risk factors and/or chronic kidney disease; Low to medium risk level (1-2): normal renal function and ≤2 risk factors

5.3. Based on the number of events projected by the CDOM and assuming the lifetime treatment costs for cardiovascular-renal disease ranging from HKD 120,796 to HKD 563,379, implementation of the JADE Program can save HKD24,082,115,482 over 15 years, i.e. HKD4,013 per patient per year. This has not taken into account hospitalizations costs for other causes, work absenteeism, loss of incomes, costs due to carers and nursing home and human suffering.

	No of events (HA)	No of events (PPP-JADE)	No of events prevented	% reduction	Cost per event (HKD)	Total cost saving (HKD) over a 15-year period
CHD	58,504	51,968	6,536	11.17	120,796	789,612,045
Stroke	52,490	39,798	12,692	77.64	308,004	3,909,386,971
ESRD	81,837	47,432	34,405	42.04	563,379	19,383,116,467
Death	141,298	93,501	47,796	33.8	Age-dependent	Age-dependent

5.4. According to the HA Report in 2015, the cost of a specialist clinic visit was HKD 1,130; GOPC visit, HKD 410; community nurse visit, HKD 450 and one hospital night in general/convalescent ward, HKD 4,330. The average cost of an evidence-based diabetes comprehensive assessment with nurse explanation averages around HKD 2,500. According to international guideline, a person with diabetes requires 4-6 clinic visits, an annual comprehensive assessment with education, essential drugs and laboratory tests, which cost on average, HKD 10,000-12,000/year.

5.5. By establishing a network of trained doctors with support from a

Diabetes Centre linked to the JADE Registry, we shall provide alternative options to the community at large for health protection. To increase its accessibility and affordability, this evidence-based integrated care program can be jointly subsidized by the HA, Bureau and insurers with monitoring by an independent party with credentials to ensure its effective implementation with ongoing evaluation of cost-effectiveness and acceptability by payors, patients and care providers.

6. Policy implications and recommendations

6.1. The general public should be made aware of the common, potentially devastating but highly preventable and treatable nature of diabetes and its complications. By increasing the transparency of all service charges and treatment costs, we shall empower the community regarding the concepts of costs versus values of health services, importance of self care and their impacts on health, wealth and quality of life.

6.2. By comparing the values of an evidence-based diabetes care program for prevention versus the high costs of treatment of critical illnesses, we shall empower our citizens to make informed decisions on selection of health care services, care providers and treatment based on their affordability, value system and personal preference.

6.3. Apart from serving as an educational tool for both patients and care providers, notably non-specialists and allied health workers, the Risk Stratification Engine of the JADE Program can effectively identify patients with different risk profiles which can increase the efficiency of care triage for management by specialists and/or family doctors.

6.4. Using information technology, the incorporation of the JADE Program including the risk engine, reporting templates with trend lines and ranges of target values as well as decision support based on attained treatment targets can further enhance the HA diabetes care model to reduce hospitalization and critical illness.

6.5. The establishment of a network of private doctors to provide quality diabetes care, supported by Diabetes Centres which focus on assessment and education linked to the JADE Registry, will create an alternative care model, to be contracted by payors such as HA or insurers which will allow HA to prioritize its services for the sick, poor and needy patients.

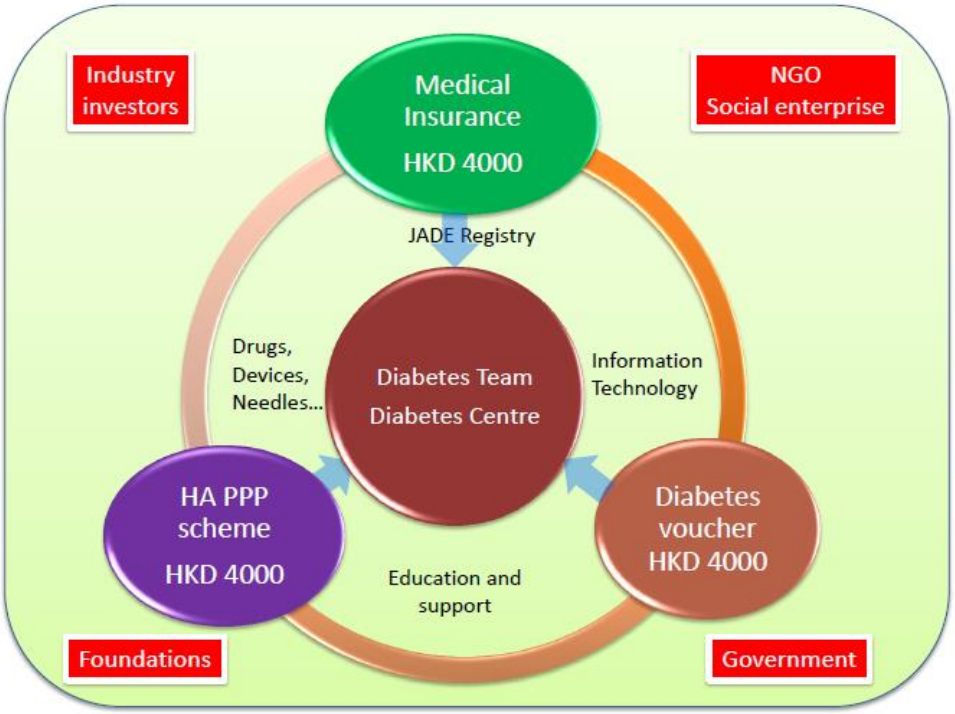
6.6. The implementation of the JADE Program through PPP with support from the Government, industry and non-governmental organizations will nurture a stable doctor-patient relationship essential for health promotion, disease prevention and treatment maintenance in order to

prevent avoidable hospitalizations, disabilities and premature death.

6.7. Apart from an aging population, the rising number of young-to-middle aged subjects with diabetes forms a large pool of extremely high risk subjects for premature disabilities and death due to long disease duration, complex clinical course, frequent default and non-adherence.

6.8. This dual burden of aging and premature chronic diseases will continue to escalate health care utilization, reduce societal productivity and compromise quality of life calling for urgent measures to reduce this growing burden on our already strained health care system.

6.9. The provision of a subsidized integrated care model linking doctors and nurses to the JADE Registry, supported by a Diabetes Centre through PPP, can address these unmet needs and close the service gaps while create job opportunities for health care professionals and knowledge workers to turn Hong Kong into a hub of health care excellence.



A possible funding model where insurers, HA and Bureau can jointly contribute towards an annual diabetes care plan of approximately HKD 10,000-12,000 to promote a stable doctor-patient relationship with linkage to diabetes centre and the JADE Registry for quality assurance, while other stakeholders including but not limited to investors, industry, academia and foundation can contribute towards the establishment of these Diabetes Centres and Diabetes Teams through private-public partnership to make the program sustainable.

7. Dissemination plans

We shall discuss with relevant stakeholders before holding seminars and press conferences to publicize and explore implementation of the recommendations.

執行摘要

1. 目的

1.1 建議一項可持續發展的公私營協作計劃，以促進社區主導的糖尿病綜合護理計劃，並提供質量保證和持續評估。

1.2 使用概率結果模擬模型去預測是項公私營協作計劃在 20 年內之使用成效，包括減低糖尿病患者發展視網膜病變、心血管腎病和癌症等併發症的數目。

1.3 對推行建議中的公私營協作計劃方案進行預算影響分析。

2. 公私營協作在提供糖尿病護理方面的失衡

2.1. 香港醫院管理局（醫管局）於 2015 年的財政預算為 552.3 億港元，為市民提供超過 90%的住院護理服務和 70%的門診護理服務，後者主要與糖尿病等慢性疾病相關。雖然優質糖尿病護理可挽救生命和節省金錢，如何有效將之實行則有賴穩定的醫患關係、患者充權教育、長期藥物治療和定期檢測等。根據最新估計，香港現時約有 60 萬名糖尿病成年患者，其中 70%（約 40 萬名患者）在醫管局跟進。

2.2. 醫管局於 2015 年聘用了 45%（5,884 名）的本地註冊醫生（全港共 12,981 名），然這些受聘醫生往往需要管理超過 90%確診糖尿病患者。在私人市場，在藥物採購成本巨大差異、等級醫療收費服務、缺乏醫管局以外但需要大量時間和人力的綜合檢測和患者教育支持等大前提下，許多資深兼具專業知識和熱誠的私家執業醫生未能為市民提供優質糖尿病護理服務。

3. 使用公私營協作的綜合糖尿病護理計劃

3.1. 自 1995 年起，香港中文大學（中大）設立了香港糖尿病登記資料庫（香港資料庫），證實患者平均確診年齡約 50 歲，10 年後(即 60 歲)當中 50%的患者患有致命危疾（如心臟病，中風，癌症腎，衰竭等）和/或過早死亡。但事實上，通過使用一支穩定的醫護專業團隊以推行具臨床實證的護理計劃，利用既定臨床程序、治療目標以及對醫患的定時反饋，我們可以將包括死亡在內的致命危疾風險降低 50-70%。

3.2. 於 2007 年，我們通過教育補助金在香港中文大學基金會轄下成立了亞洲糖尿病基金會（www.adf.org.hk），並開發了具創新思維的亞洲糖尿病評估（JADE）計劃網絡，結合臨床實證的護理模式，經由已驗證的風險引擎、產生個性化報表和加入決策支持等，使醫患能夠共同作出知情的適時決定，同時更豐富了 JADE 計劃資料庫以提高護理質量。

3.3. 除了威爾斯親王醫院（威爾斯醫院）採用了 JADE 計劃外，中大於 2007 年透過捐款在香港糖尿病及肥胖症研究所轄下成立了由護士主導的丘中傑糖尿病檢測中心（http://www.yckdac.hkido.cuhk.edu.hk/en/index.html），每年為自行上門或經由醫生轉介的患者提供以 JADE 計劃輔助的綜合檢測

服務和充權教育，通過公私營協作的方式（PPP）提高糖尿病護理的質量。

4. 華人糖尿病結果模型和公私營協作計劃的成效

4.1. 在 2007 至 2015 年期間，糖尿病患者在威爾斯醫院糖尿科中心（HA-JADE：共 9,676 人）和丘中傑糖尿病檢測中心（PPP-JADE：共 3,570 人）接受檢測後的住院率和併發症病發率，均比一般患者在典型公立醫院（HA：共 3,424 人）接受標準治療的低 20-50%。

4.2. 根據 1995 年至 2007 年間在香港糖尿病資料庫登記的 9,506 名 2 型糖尿病患者的臨床和化驗數據觀察案例所得，我們開發了第一個**華人**糖尿病結果模型（**華人**糖尿病模型），並以量化人口統計學特徵、風險因素和併發症之間的相互作用，從而預測在 15 年內因多重致命危疾引致死亡的比率。這些預測率與觀察率接近，驗證**華人**糖尿病模型的有效性。

4.3. 我們把**華人**糖尿病模型應用到 40 萬類似醫管局跟進的糖尿病患者案例，並模擬出 PPP-JADE 模型的推行，可將 15 年內致命危疾的病發率減低 11-77 % 。

5. 推行公私營協作計劃的預算影響分析

5.1. 我們估計正在醫管局跟進的糖尿病成年患者約有 40 萬人，如在醫管局推行 JADE 計劃可減低住院率並節省醫管局開支達 750,519,537 港元（每名病人每年 1,876 港元），相當於醫管局年度財政預算的 1.35%。如在社區推行通過公私營協作的方式推行 JADE 計劃，可減低住院率並節省 3,253,126,108 港元（每名病人每年 8,133 港元），相當於醫管局年度財政預算的 6%）。

	JADE 風險等級	每名患者平均住院年夜數	比率(以 40 萬醫管局患者為計算單位)	患者人數	醫管局每年住院支出估計(每晚 4,330 港元)	醫管局通過 JADE 計劃管理 40 萬患者可節省的資源	每名患者每年可節省的資源
HA	1-2	1.572	11.76%	47,036	320,162,763		
HA-JADE	1-2	1.233	11.76%	47,036	251,120,030	-69,042,733	-1,468
PPP-JADE	1-2	0.386	11.76%	47,036	78,615,030	-241,547,734	-5,135
HA	3	3.492	66.22%	264,891	4,005,247,281		
HA-JADE	3	2.970	66.22%	264,891	3,406,524,749	-598,722,532	-2,260
PPP-JADE	3	1.785	66.22%	264,891	2,047,355,784	-1,957,891,497	-7,391
HA	4	7.673	22.02%	88,073	2,926,145,279		
HA-JADE	4	7.456	22.02%	88,073	2,843,391,007	-82,754,272	-939
PPP-JADE	4	4.910	22.02%	88,073	1,872,458,402	-1,053,686,877	-11,964

極高風險等級（4）：確診心血管疾病和末期腎衰竭；高風險等級（3）：≥ 3 種風險因素和/或已確診慢性腎病；低至中風險等級（1-2）：正常腎功能和 ≤ 2 種風險因素

5.2. 假設心血管腎病終身治療費用為 120,796 港元至 563,379 港元，通過公私營協作方式在社區推行 JADE 計劃可為醫管局節省 24,082,115,482 港元的

開支，即每名病人每年 4,013 港元。這還沒有包括因其他原因造成的住院費用、工作缺勤、收入損失、照顧者及養老院的費用和病患所承受的煎熬。

	危重病例 (醫管局)	危重病例 (PPP-JADE)	可預防的病發次數	可減低的病發比率	單次病發成本 (港元)	15 年內可節省的總成本(港元)
冠狀動脈心臟病	58,504	51,968	6,536	11.17	120,796	789,612,045
中風	52,490	39,798	12,692	77.64	308,004	3,909,386,971
末期腎衰竭	81,837	47,432	34,405	42.04	563,379	19,383,116,467
死亡	141,298	93,501	47,796	33.8	視乎年齡而定	視乎年齡而定

5.3. 根據醫管局在 2015 年刊發的報告中，專科門診成本每次計為 1,130 港元；普通科門診每次計為 410 港元； 社區護士門診每次計為 450 港元及一般普通病房 / 復康病房每晚計為 4,330 港元。有實證基礎的糖尿病綜合檢測包括護士講解報告的成本在內平均每次約為 2,500 港元。根據國際指引，糖尿病患者需每年定期覆診 4-6 次，綜合檢測護理教育一次、基本藥物和化驗評估在內，每年總成本約為 10,000-12,000 元。

5.4. 通過糖尿科中心與 JADE 資料庫連繫的支持下提供綜合檢測並建立已受訓的醫生網絡，我們將為整個社區提供其他可行方案，以保障市民的長遠健康。為了提高其可近性和可負擔性，這項具實證的綜合護理計劃可由醫管局，食物及衞生局和保險業界共同資助，並由具獨立公信力的一方進行監管以確保其有效施行；同時就計劃成本效益以及其可接受性對付款人、患者和護理提供者進行持續評估。

6. 政策影響和建議

6.1. 讓公眾了解到糖尿病及其併發症的普遍存在，以及其潛在破壞但可高度預防和治療的屬性。通過提高所有服務收費和治療成本的透明度，我們將賦予社區持份者明白到成本概念與醫療服務價值的相互關係，以及自我護理對健康、財富和生活質量影響的重要性。

6.2. 通過比較具實證的糖尿病防護計劃的價值和致命危疾治療的高成本數據，市民將被充權並按其負擔能力、價值取向和個人喜好去作出對醫療保健服務、護理提供者和治療選擇等的知情決定。

6.3. JADE 計劃的風險分層引擎除了作為患者和護理提供者（特別是非專科醫生和相關衛生工作者）的教育工具之外，還可以有效地識別具不同風險特徵的患者，以提高專科醫生和 / 或家庭醫生護理分類的管理效率。

6.4. 透過使用信息科技結合 JADE 計劃內的風險引擎、趨勢分析圖表、治療目標幅度以及基於達標而作出的決策支持的報告模板，可進一步增強醫管局糖尿病護理模型，以減低住院率和致命危疾包括死亡的發生。

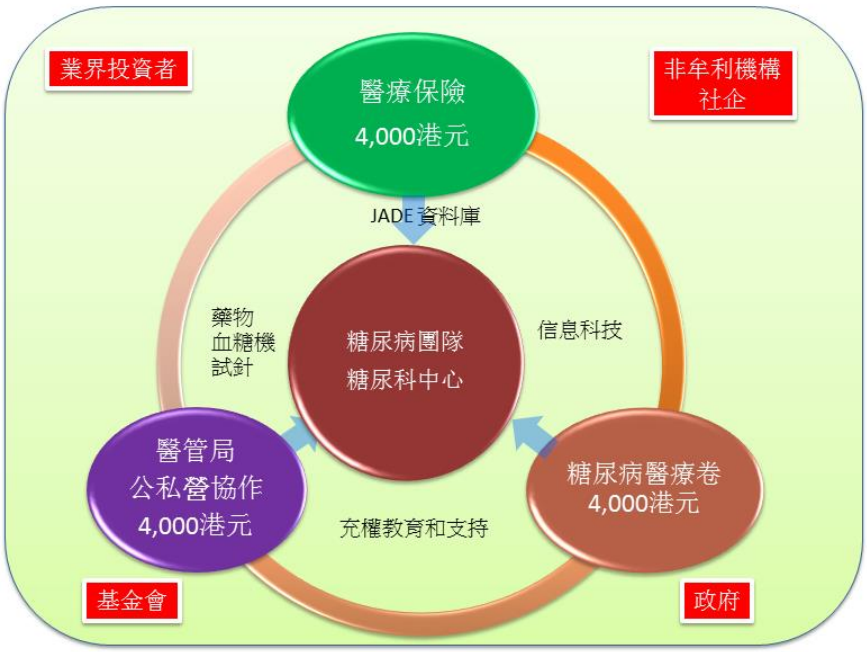
6.5. 由社區糖尿科中心支持下建立家庭醫生組織網絡，以提供優質糖尿病護理服務，並與 JADE 資料庫接軌強化綜合檢測和患者教育，共同創建另一個可行護理模型方案，讓醫管局或保險業界等付款人承包，使到醫管局能進一步優化其對貧窮及有需要病患提供更適切的醫療服務。

6.6. 在政府、業界和非牟利組織的支持下，通過公私營協作推行 JADE 計劃將培育出穩定的醫患關係，這對健康促進教育、疾病預防和治療穩定性尤為重要，同時防止可避免的住院、殘疾和過早死亡。

6.7. 除了人口老化之外，年輕及中年糖尿病患的數目持續增多，形成了極高風險的糖尿病患族群，往往由於長期病患、複雜的臨床流程、頻繁的失訪和藥物不依從性導致過早殘疾甚至死亡。

6.8. 在這種老化和過早出現慢性疾病的雙重負擔下，只會繼續加劇醫療保健的整體成本、降低社會生產力和危及生活質素。我們務必刻不容緩地採取緊急措施，從而減輕已經非常繃緊的醫療保健體系日益增加的社會負擔。

6.9. 通過公私營協作在社區推行一個補貼的綜合護理模型，並在糖尿科中心的支持下把醫護與 JADE 資料庫接軌起來，以解決目下這些迫切需要和收窄服務缺口，同時為醫療保健專業人員和知識工作者提供就業機會，讓香港成為卓越醫療保健典範的樞紐。



保險業界、醫管局和食物及衞生局可共同建構一個公私營協作下之補貼綜合護理模型。通過設立每年約 10,000-12,000 港元的糖尿病護理計劃，從而促進糖尿科中心和 JADE 資料庫的連繫以孕育穩定互信的長久醫患關係和確保服務質素。同時其他持份者包括投資者、業界、學術界和基金會等在內的群組，可從多方面透過公私營協作，設立這些糖尿科中心和糖尿病團隊，讓計劃得以持之實行。

7. 宣傳計劃安排

我們將在舉辦研討會和新聞發布會前與相關持份者進行討論，以宣傳和探討推行是項公私營協作計劃的建議。

CONTENTS

1. Rationale and background

In a recent report using public sector health records and various definitions, 697,201 people with diabetes were identified in Hong Kong, giving a prevalence of 10.29% and an incidence of 9.46 per 1000 person-years of diabetes in 2014 [1]. In 1995, as part of a quality improvement program, the Chinese University of Hong Kong (CUHK) first established the Hong Kong Diabetes Registry (HKDR) to define the causes and consequences of diabetes. Using trained nurses and guided by a protocol, 30-50 diabetic patients underwent comprehensive assessments at the Prince of Wales Hospital (PWH) Diabetes Centre including blood/urine tests and eye/feet examination [2]. Based on this comprehensive registry with an enrolment of over 30,000 patients to date, we have documented the clinical profiles of these patients characterized by young age of diagnosis, high prevalence of metabolic syndrome and insufficient insulin secretion with propensity to develop stroke, renal failure and cancer. These phenotypes are highly applicable to many Asians undergoing rapid acculturation and lifestyle transition, heralding the growing burden of aging and premature chronic disease on our health care system [3, 4].

1.1. Hong Kong Diabetes Registry (HKDR)

Amongst these patients diagnosed with diabetes, 97% of them had type 2 diabetes, with a mean age of 56 years and disease duration of 6 years, meaning that half of these patients were diagnosed before the age of 50. During a mean follow-up period of 6 years, 5% of patients developed at least one critical illness (stroke, heart disease, end stage renal disease (ESRD), cancer) or died on an annual basis. Put in another way, by the age of 60, 1 in 2 of these patients was struck by a disabling and expensive-to-treat critical illness with frequent hospitalizations and untimely death. Since many of these patients were still in their economically productive years, the loss of jobs, frequent absenteeism, reduced productivity as well as negative financial and emotional impacts on the person and his/her families are beyond description [5-7].

1.2. Integrated, team-based care for quality assurance

Since 1995, the CUHK-PWH Diabetes Team implemented a series of quality improvement programs to enhance the efficiency of delivery of diabetes service in light of growing demands and variable care standards. We adapted the best practices in clinical trials characterised by use of predefined care protocols for patients with specific risk profiles, implemented by research coordinators supervised by a medical team where care processes, attainment of treatment

targets (notably blood pressure, blood lipids, body weight, glycated haemoglobin (HbA1c)) and use of organ-protective drugs (notably statins and renin angiotensin system (RAS) inhibitors) were regularly monitored. Based on a series of studies, we had systematically confirmed the marked benefits of using a doctor, assisted by a nurse/pharmacist, guided by a protocol, in reducing death and event rates by 50-70% [8-11].

1.3. CUHK-PWH and NTEC-GOPC Shared Care Program

In the late 1990s, alongside the establishment of the HKDR, we initiated a dialogue with the Government outpatient clinics (GOPCs) in the New Territories-East Cluster to conduct a pilot shared care program, coordinated by a diabetes nurse, where clinically stable patients were referred to the GOPCs after comprehensive assessment and empowerment. These patients returned to the Centre for repeat assessment at 18-24 monthly intervals for quality assurance while the hospital-based specialists and GOPC-based family doctors held regular meetings to discuss cases and share knowledge. At the same time, processes and toolboxes such as patient handbook and structured referral form were used to increase information transparency with particular emphasis on rights and roles of both parties to promote shared and informed decision. In 1998, the CUHK-PWH was awarded the Best Hospital Authority (HA) Program and the Best HA Team for this quality improvement initiative [12].

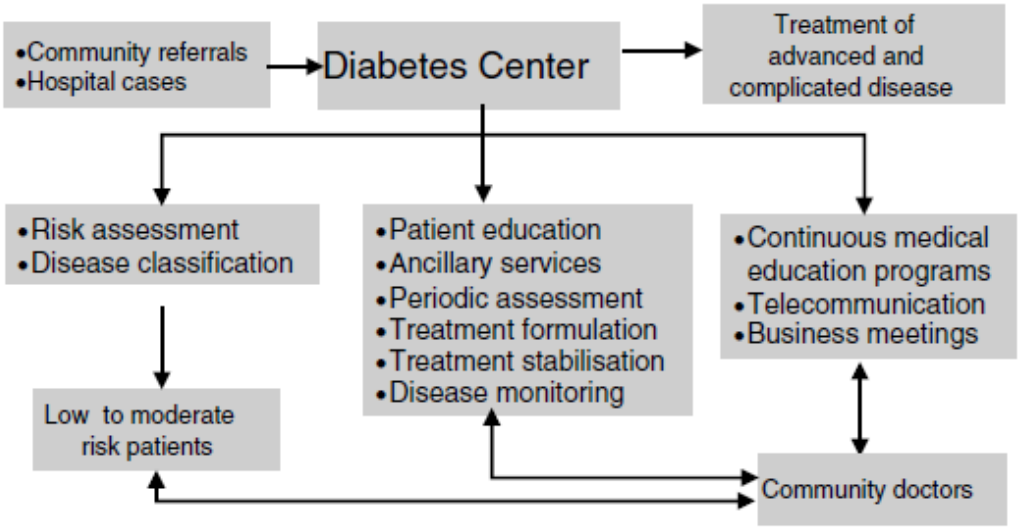


Figure 1 The CUHK-PWH Shared Care Program where nurses, supported by endocrinologists, were trained to conduct regular comprehensive assessment and education programs and establish a registry for quality assurance. This was followed by triage of patients to appropriate care settings, coordinated by a shared care nurse, for promoting communication amongst all relevant stakeholders [13].

While many private doctors were keen to participate in this shared care program, this was hampered by huge cost differentials, notably drugs and laboratory tests, between the private and public sector and lack of patient educational support outside the HA setting, which requires 4-6 hours upon diagnosis, and frequent reinforcement totalling 24 hours of contact time to sustain improvement [14]. While there are ongoing HA shared care programs, multiple administrative procedures and need of patients to return to the hospital for blood tests or clinical assessment as well as limited drug choices reduced its user-friendliness for both patients and care providers.

With increasingly young age of diagnosis, there are few, if any, options which are convenient and affordable for our young-to-middle-aged workforce. These subjects often cannot afford to take time off work, resulting in frequent default, poor treatment adherence and suboptimal control of risk factors [15]. Given their high risk for complications, a convenient and personalized service is urgently needed to change their clinical course and protect their health.

1.4. HKDR Risk Equations for risk stratification and care triage

In 2005, using data from more than 6000 type 2 diabetic patients enrolled in the HKDR with an accrual of over 3000 clinical events based on hospital discharge summaries using the International Classification of Disease (ICD-9) Codes in the HA Clinical Management System (HA-CMS), we developed a series of risk equations comprising various combinations of 11 risk factors to predict 5-year probabilities of stroke, heart failure, coronary heart disease (CHD), ESRD, cancer and death with 70-90% sensitivity and specificity [2].

1.1. Risk assessment and empowerment program

In 2000, the HA gradually introduced the diabetes comprehensive assessment services to other hospitals by creating ambulatory diabetes centres, away from the busy medical outpatient clinics and wards. In anticipation of the growing service demands, the HA created new career paths for diabetes nurse specialists who work closely with endocrinologists to provide regular comprehensive assessment, education and empowerment services to diabetic patients attending the HA hospitals. These services are provided within the setting of a day centre in order to reduce unnecessary admissions for complex issues which cannot be adequately handled in busy clinics with 5-10 minutes of consultation time and frequent changes of doctors at each visit.
To date, Hong Kong has more than 100 practising diabetes nurses and 100

endocrinologists and 17 diabetes centres which provide and coordinate these diabetes assessment and education services in the public sector. The HA also adopted a database structure similar to the HKDR in the HA-CMS to guide data collection during comprehensive assessment. In 2009, the HA extended this program to the GOPCs to benefit more patients in the community [16, 17].

1.5. Growing demand for HA diabetes services

Since the introduction of this comprehensive risk assessment and empowerment program in the HA system, there are notable improvement in the care standards as reflected by control of risk factors such as declining HbA1c levels and increasing prescription of life-saving drugs. However, the huge private-public differentials in treatment costs, in part due to different acquisition costs of drugs and laboratory tests as well as fee-for-service in the private sector as compared to a nominal charge in the public sector, have resulted in the majority of patients with chronic disease, notably diabetes, opting for care in the public sector. To date, over 330,000 diabetic patients have been registered in the HA Diabetes Database.

1.6. Care fragmentation, clinical inertia and non-adherence

Currently, the HA budget is growing at 5-10% annually with the latest budget well above HKD 55,000 million. This budget represents approximately 17% of the government revenue which is used to employ 45% of the registered doctors to look after nearly 90% of patients, ranging from those with mild ailments to those with multi-organ failure [18]. These literally free services to all has led to increasingly long waiting list for clinic consultations, inappropriate use of emergency room services, suboptimal working environment and low staff morale. From a patient perspective, the short consultation time, long follow up intervals, frequent changes of attending doctors, lack of a stable doctor-patient relationship, variable care standards, insufficient education on self management, infrequent review of treatment regimens and inappropriate use of medications have culminated to frequent default, drug wastage, poor treatment adherence and poor control of risk factors. The overall consequences are care fragmentation, delayed intervention, drug wastage and unnecessary hospitalizations.

1.7. Single payor versus multiple payors

Currently, the HA is providing services which are more than 90% subsidized despite the lack of a long term funding scheme such as mandatory health

insurance schemes or taxation to support the growing demand for health services. These publicly-funded high quality systems which are available in Europe can only be sustained by a high taxation rate, e.g. 30% along with a national health insurance scheme [19]. However, with rapid advancement in technology and increasing expectations from patients, such a system is becoming increasingly difficult to sustain given competing societal needs, finite resources and inevitable economic cycles. Even in UK well known for its National Health Services, there are similar challenges with long waiting list, delayed intervention, low staff morale and patient dissatisfaction [20].

Over-reliance on a single public system without an effective mechanism to triage patients into settings which are most appropriate to their individual needs, taking into consideration factors such as practical constraints, clinical conditions and socioeconomic status, can reduce the efficiency and effectiveness of service delivery. In order to reduce gaps and overlaps, there is a need to maximize all available resources in the private and public sectors to make our health care system sustainable. [13].

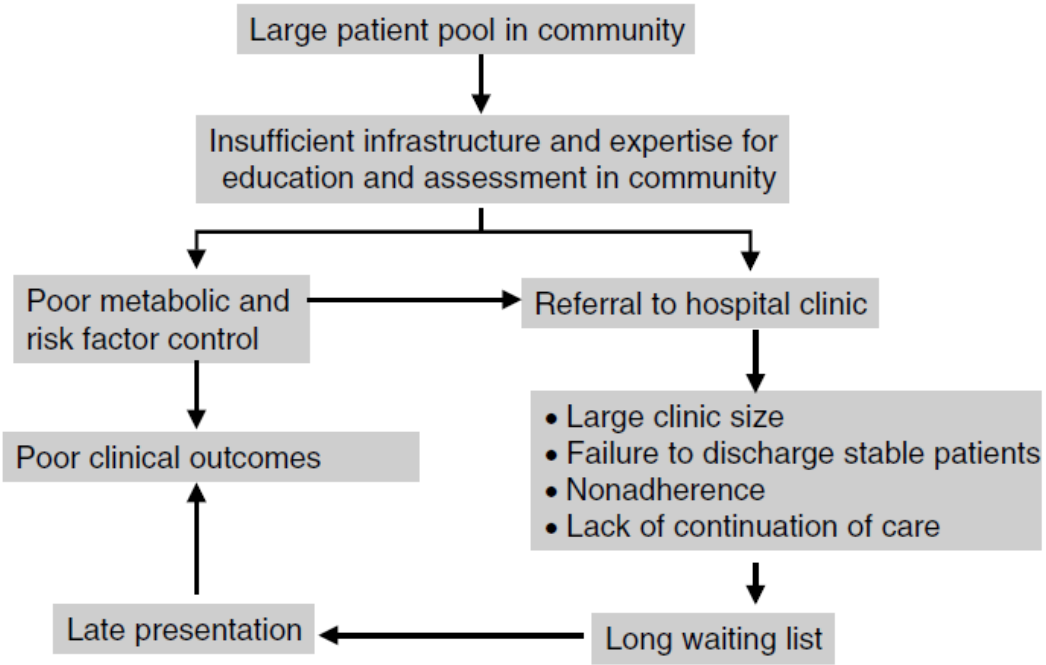


Figure 2 Insufficient risk assessment and education in the community, lack of care integration between primary and hospital care teams as well as that between the private and public sectors often result in delayed treatment and non-adherence culminating in utilization of health care resources which are often avoidable [13].

In the case of diabetes, each patient is unique in terms of his/her risk profiles, educational needs and clinical care. With technological advancement, the complex aetiologies of diabetes have become increasingly evident. To address

the pluralistic needs of these patients over a lifetime, the importance of periodic assessments, appropriate drug selection from a growing list of novel compounds and the use of cognitive-psychological-behavioral strategies to address emotional needs and promote self management cannot be emphasized enough [21-24]. In order to best use our finite resources, there should be reasonable sharing of resources amongst family doctors, specialists and allied health professionals in both private and public sectors. This dual system is particularly important to Hong Kong with its low tax system and lack of compulsory health insurance scheme.

1.8. Quality diabetes care through monitoring and partnerships

In the best scenario, these are the possible options of diabetes care delivery:

1. Patients with early and controlled disease can be seen by primary care doctors with periodic review by specialists every 2-3 years to detect silent deterioration, identify unmet needs and jointly review treatment plans.
2. Patients with advanced and unstable disease, often affecting multiple systems, can be seen by both specialists and family doctors with frequent communications for formulating diagnosis and treatment plans.
3. Patients who require and can afford a more personal and user-friendly service can be seen by private doctors with subsidies and incentives to both patients and care providers in order to reduce the service load in the public sector which can focus on providing care to the sick and socially deprived.
4. Due to the silent nature of diabetes, patients should be linked to a registry for quality improvement and monitoring with regular feedback to relevant stakeholders to maintain standards and promote informed decisions [25].

1.9. Doctors in the private sector – untapped resources

Despite their experiences, expertise and commitment, many private doctors who represent over 50% of the medical workforce, have been deprived of opportunities to apply their knowledge and skills to manage patients with diabetes at a stage when care is still highly affordable. Apart from wastage of this valuable human resources, the dominance of HA in providing chronic care with the aforementioned consequences, has led to a situation where a stable doctor-patient relationship cannot be developed, neither in the private nor public sector. In the case of diabetes and chronic disease, this doctor-patient relationship holds the key to successful management where doctors need to learn the attributes and needs of his/her patients, sometimes including their families, in order to make the most appropriate decisions for protecting

his/her health [21].

1.10. Using academia to build capacity in the community

In 1992, the CUHK launched the first Diploma Course in Diabetes Management and Education (DDME) and later, the Master Course in Endocrinology Diabetes and Metabolism (MEDM) with quotable qualifications by the Medical Council of Hong Kong to build capacity and improve chronic care in the community. To date, more than 600 health care professionals, half of whom are doctors, have graduated from these courses. http://www.hkido.cuhk.edu.hk/Programmes/MScinEndocrinology,DiabetesandMetabolism/OverviewandObjectives.aspx.

In 2007, supported by an educational grant, we set up a charitable foundation governed by the CUHK Foundation, the Asia Diabetes Foundation (ADF) (www.adf.org.hk) to develop the first-ever web-based Joint Asia Diabetes Evaluation (JADE) Program with built-in care protocols, validated risk engines, personalized reporting and decision support to promote team-based integrated care and establishment of a registry for quality improvement [26, 27].

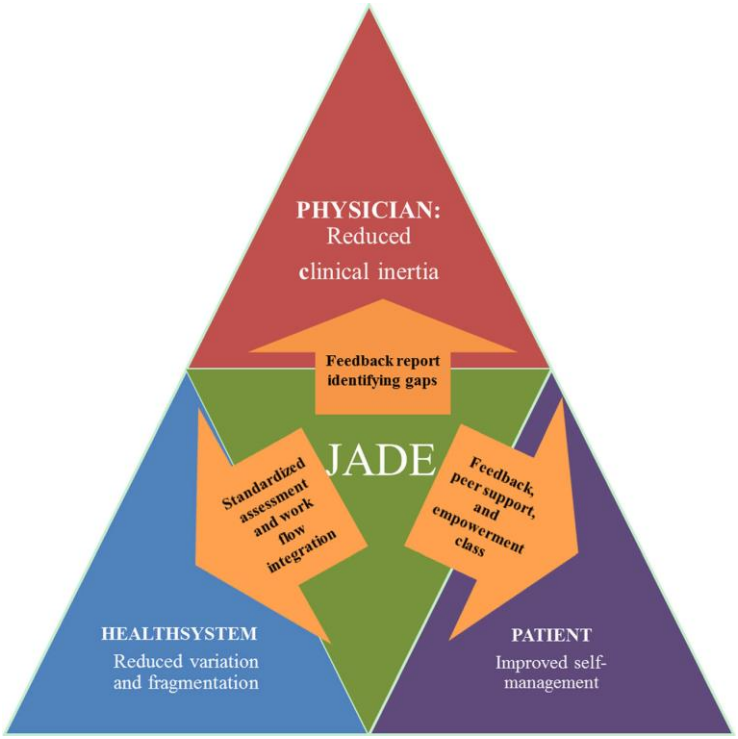


Figure 3 A diagram summarising the key features of the web-based JADE Program targeting at physicians to reduce clinical inertia, health system to reduce care variation and fragmentation and patient to promote self management[28].

In the same year, supported by a donation, a CUHK-affiliated nurse-led

diabetes centre, the Yao Chung Kit Diabetes Assessment Centre was set up to implement the JADE Program which involves comprehensive risk assessment, issue of the JADE personalized report and patient empowerment on a self-financed basis. http://www.yckdac.hkido.cuhk.edu.hk/en/index.html

The mission of the CUHK-affiliated ADF and YCK Diabetes Centre is to use private public partnership (PPP) to fill the much-needed but highly affordable service gaps in terms of comprehensive risk assessment and education, in accordance to international guidelines, so as to bring out the best of medical expertise and technologies for preventing diabetes and its complications. In collaboration with other stakeholders including industry and non government organizations (NGOs), the ADF and YCK Diabetes Centre conduct regular outreach programs to raise awareness, empower the community and detect people with undiagnosed, untreated or uncontrolled diabetes for intervention.

2. Evaluation of integrated care using private public partnerships

2.1. Objectives

1. To propose a sustainable PPP scheme to promote community-based diabetes integrated care programme with quality assurance and ongoing evaluation.
2. To project the effect of the PPP scheme within 15 years in terms of reducing the number of diabetic patients developing complications using a probabilistic outcomes simulation model.
3. To perform budget impact analysis for implementing the proposed PPP scheme.

2.2. Methods and materials

Since the implementation of various pilot programs in a natural environment in 2007, we have collected comprehensive data from different care settings to evaluate their impacts on individual health and utilization of health care resources. In this analysis, we compared the clinical outcomes and hospitalization rates amongst Chinese patients with type 2 diabetes managed in three settings, two in the public sector, the Alice Ho Nethersole Hospital (AHNH) and Prince of Wales Hospital (PWH) as well as one in the private sector, YCK Diabetes Centre in collaboration with private doctors, many of whom are holders of DDME or MEDM qualifications.

2.3. HA diabetes care model

The HA offers comprehensive assessment at 17 Diabetes Centres, including the ones based at PWH and AHNH, using a similar protocol including eye, feet, blood and urine examinations. However, the follow up actions after performance of this assessment can vary considerably amongst these Centres depending on practices and availability of resources.

The AHNH care model is an example of HA models where nurses perform comprehensive assessments in 30-50 patients weekly at the Diabetes Centre. However, the issue and explanation of the 2-page HA summary listing complications and risk factors available in the HA intranet, is entirely at the discretion of the attending doctors or clinical teams concerned. Since 2009, as a collaborative partner, the AHNH entered the results of the assessment into the JADE portal although they did not issue or explain any of the JADE reports to their patients due to insufficient manpower, a scenario fairly representative of most HA settings. The JADE reports with clinical recommendations on disease monitoring and treatment adjustments are also not readily available to the attending doctors.

2.4. HA-JADE-enhanced diabetes care model (PWH)

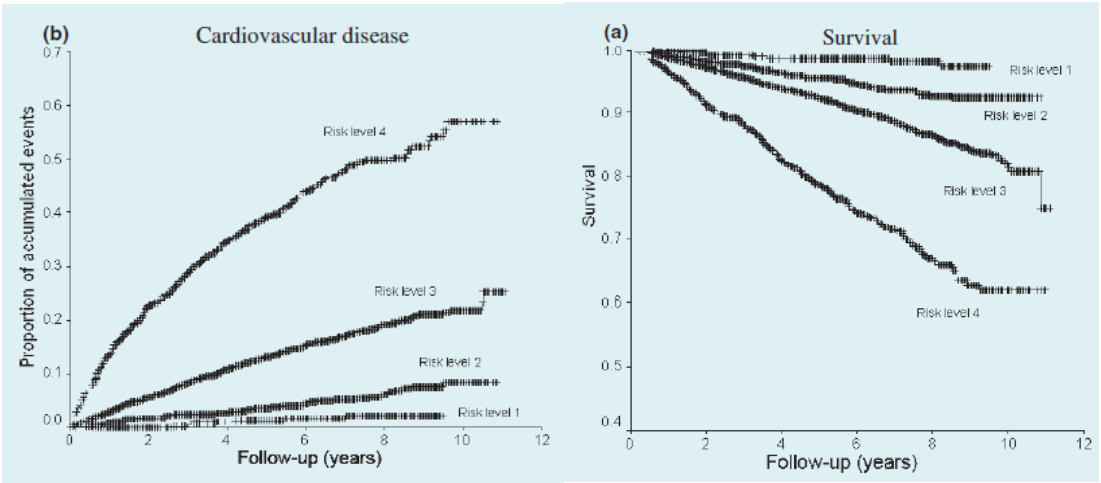
Since the launching of the shared care program in 1995, the CUHK-PWH Diabetes Centre has always arranged patients to return 4-6 weeks later after the comprehensive assessment to receive a simple-to-read report with nurse education followed by care triage into various clinics. This practice continued with the introduction of the JADE Program to the PWH in 2007 where patients received a personalized report complete with risk categories, attainment of treatment targets and practice tips during a 2-hour group empowerment session (usually 20-25 patients per class).

Apart from explaining to patients on how to interpret the risk categories and emphasizing the highly modifiable nature of HbA1c, blood pressure, LDL-C and body weight, the nurses also assist doctors to use these results and triage patients into various clinics. By identifying difficult-to-treat patients during these assessments, prompt follow-up actions such as referral to nurse clinics and peer support can be taken [24, 29, 30]. Despite support from nurses, these patients are often seen by different doctors with short consultation time at each clinic visit, typical of a public hospital setting. The recommendations on treatment intensification or adjustment by the endocrinologist written in the

JADE report may not be noted or followed.

Table 1 The JADE risk stratification program which uses various combinations of risk factors (age, sex, disease duration, smoking, blood pressure, lipids, HbA1c, obesity, renal function, foot examination, retinopathy, cardiovascular-renal complications, various cut-off points of HKDR risk scores) to categorize patients into very high (4), high (3), medium (2) and low (1) risk with corresponding annual cardiovascular event and/or death rates of 8, 5, 3 and less than 1% (lower panels). Based on these risk categories, a care plan with follow up intervals and treatment goals are recommended [31].

Risk stratification	Very-high risk 4	High risk 3	Medium risk 2	Low risk 1
Cardiovascular renal complication	≥ 1	0	0	0
Any risk score	NA	≥ SP	≥ ST and < SP	< ST
Stratification parameters	NA	≥ 3	2	0–1
eGFR	NA	< 60	60–< 90	≥ 90
Recommended number of medical visits per year	6 or more	4 or more	3 or more	At least 2
Comprehensive assessment	Every 12–18 months			
Other recommendations	Counselling/laboratory tests/telephone calls between medical visits			



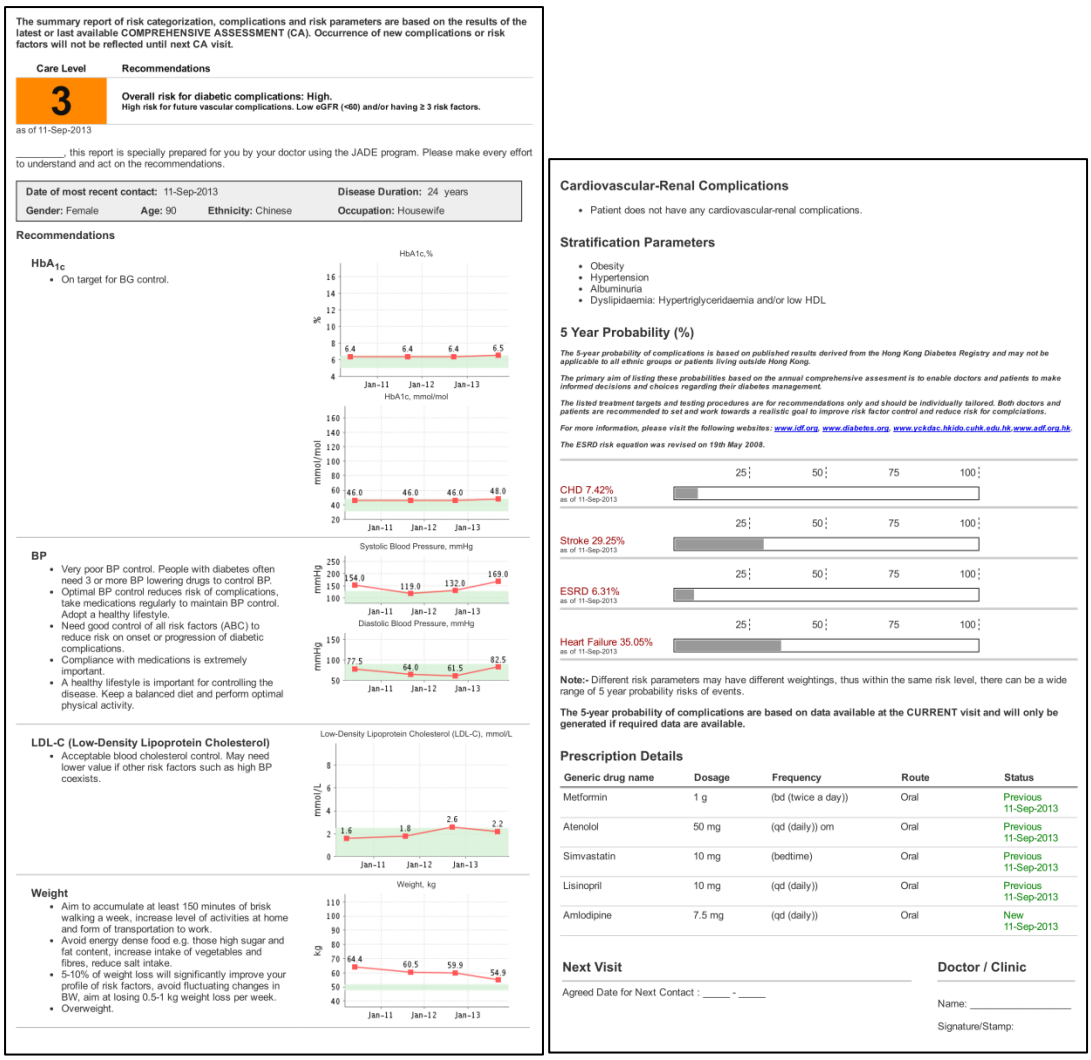


Figure 4 A sample of a JADE Report, complete with risk factors, complications, risk categories, 5-year probabilities of critical illness, trends of modifiable treatment targets and decision support for both doctors and patients, which aims to promote shared decisions, reduce delayed intervention (clinical inertia) by doctors and treatment non-adherence by patients in order to attain multiple treatment targets.

2.5. PPP-JADE enhanced diabetes care model (YCK Centre)

In this PPP model, patients can refer themselves, or doctors from either the private or public sector can refer their patients to the YCK Centre for comprehensive assessment and education on a self-funded basis using the JADE portal (HKD 2200 for a 4-hour session). Both doctors and patients receive the JADE report with written recommendations by the CUHK-PWH endocrinologists. The majority of referring doctors are either specialists or family doctors with quotable qualifications for diabetes management. The patients usually return to the Centre to collect the JADE report with 20-30 minute explanation by a diabetes nurse with emphasis on healthy lifestyle, treatment to multiple targets, treatment adherence, regular follow-up visits

and self-monitoring of blood glucose. They are also pre-booked for repeat assessment in the following year with reminder a week before the visit is due.

For patients who are not regularly followed up, they will be recommended to seek treatment from a list of private doctors in our network or public sector, as appropriate. Some of these patients attend both private and public clinics to receive 1) personal advice from their family doctors, 2) JADE assessment and nurse education from the YCK Centre and 3) low cost drugs and investigations in the HA clinic. The following diagram summarises the possible flow of patients amongst the private doctors, YCK Diabetes Centre and HA clinics.

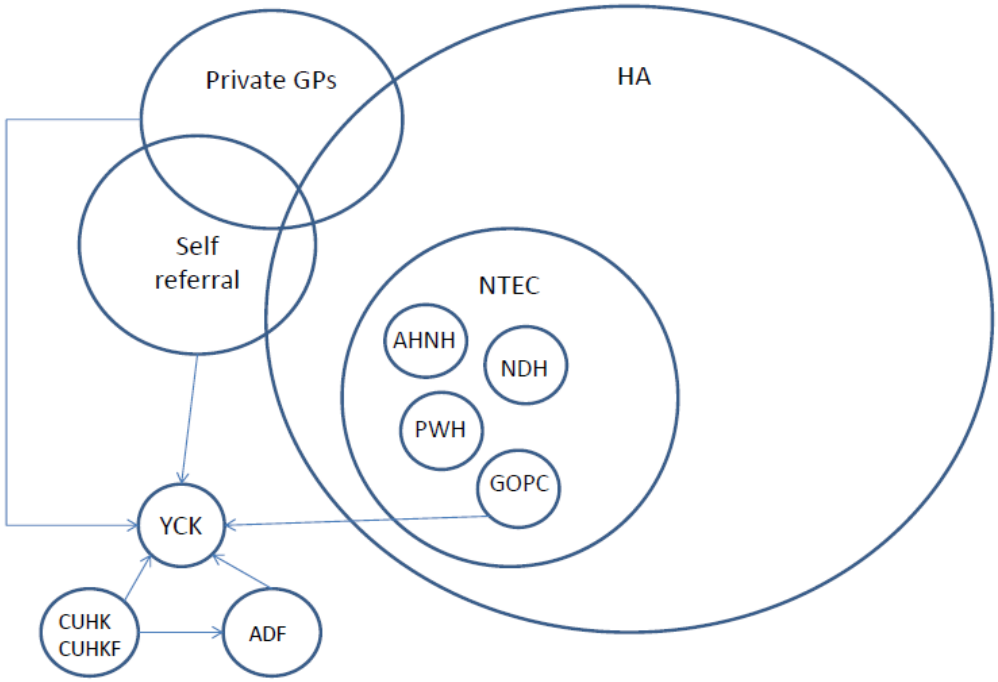


Figure 5 A schematic diagram showing the distribution of patients in the public and private sector with implementation of the JADE Program in the PWH and CUHK-affiliated YCK Centre to support patients managed predominantly by private doctors through private public partnerships.

In summary, while the AHNH model provides comprehensive assessment, typical of a HA setting, the HA-JADE model implemented at the PWH adopts the JADE Program to generate a personalized report followed by group empowerment. In the PPP-JADE model implemented through the YCK Centre, apart from undergoing comprehensive assessment with issue of the JADE report, this is accompanied by detailed explanation on an individual basis. Importantly, these patients usually receive care from the same doctor who can take early actions to optimize care and reinforce adherence. The pre-booking

of a repeat assessment in the following year with recall also ensures that these patients are not lost to follow up and remain part of the health care system.

Table 2 A table summarising the distributions of various care components in the HA, HA-JADE and PPP-JADE models. The latter represents the best scenario where patients undergo periodic assessment and empowerment by nurses with access to a stable doctor-patient relationship and regular recall by the Centre to reduce default.

	Risk assessment	JADE Report	Group education	Individual education	Same doctor FU	Out of pocket
HA	✓					
HA-JADE	✓	✓	✓			
PPP-JADE	✓	✓		✓	✓	✓

FU=follow up

2.6. Statistical analysis

We retrieved data registered between 2007 and 2015 in the JADE portal entered by the YCK Centre, PWH and AHNH as 3 diabetes care models (HA, HA-JADE, PPP-JADE). All clinical outcomes based on ICD-9 codes were censored from the HA-CMS using the unique identity card number. The total number of hospitalization days was counted during the observational period. Analysis was performed using R (version 3.2.4). All data are expressed as mean (SD) or median (interquartile range [IQR]), as appropriate. The Chi Square test, Fisher's exact test, Wilcoxon paired test, Mann-Whitney test, Student's t test were used for group comparisons. Cox regression model was used to estimate the independent effect of different care model (using HA as referent) after adjustment for confounders. For hospitalization data, we used zero-inflated negative binomial regression to estimate the effect size of different confounders including:

1. model 1: age, sex, age of onset, care models (HA, HA-JADE, PPP-JADE)
2. model 2: variables in model 1 and JADE risk categories (category 4, 3, 2 and 1 combined);
3. variables in model 2 and college education (>11 years of education)
4. variables in model 3 and use of statins and RAS inhibitors.

A p value less than 0.05 (2-tailed) was considered significant.

2.7. Results

There were 16,670 patients in the entire dataset with the first patient recruited on 28/11/2007 and last patient recruited on 29/05/2015. Of these, 3,570

patients were managed predominantly at the AHNH (HA), 9,676 at the PWH (HA-JADE) and 3,424 by predominantly private doctors supported by the YCK Centre (PPP-JADE). Table 1 summarises the clinical profiles, drug use, number of events and annual incidence rate (per 1000 patient-years) of each event during a mean follow-up period of 3.74 years. Amongst the 7 critical illnesses, chronic kidney disease had the highest incidence with a mean annual incidence of 6.5% followed by cardiovascular disease (1.5%), death (1.4%) and cancer (0.7%), giving a total of 14% per year. Despite similar age, sex distribution and disease duration, patients in the JADE-PPP model had the lowest event rates followed by the HA-PPP and HA models.

Table 3 Clinical profiles, number of events (n) and incidence with 95% confidence intervals (per 1000 patient- years) of critical illness in 16,670 Chinese type 2 diabetic patients observed between 2007 and 2015 receiving usual care in HA, JADE enhanced care at the PWH (HA-JADE) and predominantly private care with annual assessment at the YCK Centre using the JADE Program (PPP-JADE).

	All	HA	HA-JADE	PPP-JADE
Number	16670	3570	9676	3424
Age (years)	60.22±11.58	59.9±11.73	60.69±11.67	59.23±11.08
Male	54.48%	54.29%	53.15%	58.41%
Duration of diabetes (years)	8.9±8.12	8.97±8.24	9.4±8.19	7.42±7.57
Follow up period (years)	3.74±1.77	3.21±1.56	3.45±1.54	5.13±1.88
CHD (n)	406	72	248	86
incidence	7.47 (6.78-8.23)	7.19 (5.71-9.06)	8.59 (7.58-9.72)	5.56 (4.5-6.87)
Heart failure (n)	267	55	157	55
incidence	4.44 (3.94-5.01)	4.93 (3.79-6.42)	4.93 (4.22-5.77)	3.21 (2.47-4.17)
Stroke (n)	299	66	166	67
incidence	5.24 (4.68-5.87)	6.39 (5.03-8.13)	5.47 (4.7-6.37)	4.09 (3.22-5.19)
CKD (n)	2836	676	1638	522
incidence	65.49 (63.12-67.95)	86.6 (80.32-93.39)	73.01 (69.56-76.64)	39.96 (36.68-43.54)
ESRD (n)	789	172	495	122
incidence	13.02 (12.14-13.96)	15.6 (13.44-18.11)	15.32 (14.03-16.74)	7.06 (5.92-8.43)
Cancer (n)	432	71	251	110
incidence	7.4 (6.74-8.13)	6.56 (5.21-8.28)	8.09 (7.15-9.15)	6.66 (5.53-8.03)
Death (n)	895	174	571	150
incidence	14.34 (13.44-15.32)	15.19 (13.09-17.62)	17.11 (15.76-18.57)	8.54 (7.28-10.03)
All events	6851	1544	4147	1160
incidence	156.67 (153.01-160.43)	195.29 (185.79-205.28)	182.71 (177.24-188.36)	88.38 (83.45-93.62)

CKD=chronic kidney disease; CHD=coronary heart disease; ERSD=end stage renal disease

Table 4 A summary of the clinical profiles, attainment of treatment targets and drug use in type 2 diabetic patients receiving HA, HA-JADE and PPP-JADE care.

		HA	HA-JADE	PPP-JADE
Number		3570	9676	3424
Male		54.29%	53.15%	58.41%
Risk Level	1	2.66%	1.93%	2.92%
	2	9.22%	7.51%	15.25%
	3	65.15%	66.73%	65.92%
	4	22.97%	23.83%	15.92%
Young onset diabetes		17.48%	15.68%	12.42%
Family history of diabetes		52.83%	57.04%	57.71%
Use of tobacco	Ex	21.41%	20.42%	19.63%
	Current	13.67%	10.96%	11.16%
Highest education	Primary or illiterate (<6 years)	47.32%	44.56%	33.78%
	Middle School (6-11 years)	39.50%	40.47%	38.14%
	High School (≥11 years)	4.99%	5.04%	8.21%
	College	7.79%	9.83%	19.73%
Anti-diabetic treatment	Lifestyle	7.88%	8.05%	17.20%
	Oral drugs only	64.72%	63.07%	71.04%
	Insulin only	6.98%	6.33%	2.69%
	Oral drugs and insulin	20.42%	22.54%	9.07%
Use of RAS inhibitors		35.27%	49.05%	40.73%
Use of statins		29.18%	46.94%	34.77%
Any diabetic retinopathy		30.12%	27.00%	23.62%
Sensory neuropathy		2.49%	7.48%	4.59%
Microalbuminuria		27.19%	27.42%	22.23%
Macroalbuminuria		16.99%	16.51%	8.94%
History of cancer		5.15%	6.61%	4.88%

History of coronary heart disease		12.77%	13.39%	11.30%
History of heart failure		2.97%	4.55%	1.87%
History of stroke		9.80%	9.11%	5.67%
History of peripheral vascular disease		2.69%	4.72%	2.63%
History of cardiovascular disease		22.69%	23.08%	17.17%
History of end stage renal disease		2.13%	1.61%	0.38%
History of chronic kidney disease		22.44%	23.59%	16.12%
Any history of complications		40.78%	42.18%	29.94%
HBA1c<7%		36.62%	40.21%	50.96%
BP<130/80 mmHg		36.54%	29.78%	41.47%
LDL-C<2.6 mmol/L		43.44%	57.04%	48.38%
Number of ABC targets attained	0	24.54%	19.14%	17.87%
	1	41.65%	43.75%	36.24%
	2	27.34%	29.43%	33.53%
	3	6.47%	7.68%	12.35%

Young onset diabetes: age of diagnosis<40 years

Table 5 A summary of continuous variables including risk profiles and attainment of treatment targets of type 2 diabetic patients at baseline in 3 different care settings (HA, HA-JADE, PPP-JADE).

	HA		HA-JADE		PPP-JADE	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	59.90	11.73	60.69	11.67	59.23	11.08
Disease duration (years)	8.97	8.24	9.40	8.19	7.42	7.57
Waist (male)	90.07	10.52	93.04	11.06	90.72	9.96
Waist (female)	85.73	11.06	88.21	11.31	85.41	10.41
Body mass index (kg/m^2)	26.22	4.34	26.28	4.54	25.49	3.97
HbA1c (%)	7.78	1.62	7.60	1.55	7.35	1.60
Systolic blood pressure (mmHg)	135.65	18.49	137.67	18.85	131.47	18.30
Diastolic blood pressure (mmHg)	75.94	10.40	79.44	10.79	77.21	9.93
Total cholesterol (mmol/L)	4.89	1.05	4.54	0.94	4.71	0.96
HDL-C (mmol/L)	1.34	0.38	1.31	0.38	1.27	0.33
LDL-C (mmol/L)	2.77	0.94	2.50	0.84	2.67	0.93
Triglyceride (mmol/L)	1.69	1.31	1.61	1.51	1.67	1.41
Serum creatinine (umol/l)	92.32	77.16	92.59	66.24	84.35	33.93
Estimated GFR (ml/min/1.73m^2)	83.85	28.21	80.68	26.47	84.06	22.51
Urinary Alb:Cr ratio (mg/mmol)	31.25	101.14	28.69	89.74	12.86	47.16

SD=standard deviation; GFR=glomerular filtration rate; ACR=albumin:creatinine ratio

Tables 4 and 5 listed the clinical profiles and control of risk factors in these patients managed by different care models. These patients shared similar demographic profiles with a mean age of 58 years and 8 years of disease duration, re-affirming that half of these patients were diagnosed at the age of 50. Over 50% of these patients gave a positive family history of diabetes and 12-20% of them were diagnosed before the age of 40 suggesting a strong familial predisposition.

We have reported that patients with young-onset diabetes had 50% higher risk for all clinical events and premature death compared to their counterparts with late onset disease. Despite their vulnerability, they were most likely to default and non-adherent to medical recommendations due to competing priorities and complacency [7, 15]. Furthermore, these patients are highly heterogeneous in

terms of their genetic profiles and causes for diabetes which call for more individualized treatment and early use of medications to avoid metabolic decompensation [32].

Compared to patients attending the public sector, patients receiving the PPP-JADE care tended to be more educated with higher rates of attainment of treatment targets. Over 20% of patients had been smokers and 10% were active smokers. More than 30% of patients already had some forms of microvascular and/or macrovascular complications and/or cancer at the time of registration.

Despite having similar disease duration, patients in the public sector were more likely to be treated with insulin but had worse glycemic control. Similarly, 30-40% of patients were treated with organ-protective drugs, notably statins and RAS inhibitors, more so in the public sector. Despite receiving fewer drugs than their peers in the public sector, patients in the PPP-JADE model were twice more likely to attain all 3 treatment targets for HbA1c, blood pressure and LDL-C which have been shown to reduce clinical events including death [33].

Treatment non-adherence is a major challenge in management of patients with silent conditions such as diabetes [34]. Thus, the suboptimal risk factor control despite heavy use of medications raised the possibility of non-adherence due to insufficient explanation and support in the busy HA setting. In our previous study, 50% of patients attending HA clinics treated with 5 or more chronic medications were non-adherent. These complex treatment regimens reflected the high risk nature of these subjects. In these patients, treatment non-adherence (30% or less) was associated with 3-fold higher risk of death than those who took at least 70% of the treatment regimen [11].

Table 6 A summary of the clinical profiles, attainment of treatment targets and use of medications at baseline in type 2 diabetic patients stratified by JADE Risk categories

		Risk Level 1-2	Risk level 3	Risk level 4
Number		424	2326	820
Male gender		53.30%	52.32%	60.37%
Young onset diabetes		17.49%	19.92%	10.38%
Family history		51.89%	55.33%	46.22%
Use of tobacco	Ex	10.14%	20.81%	28.94%
	Current	7.08%	15.18%	12.82%
Anti-diabetic treatment	Lifestyle	12.03%	6.97%	8.30%
	Oral drugs only	74.53%	64.61%	59.95%
	Insulin only	3.54%	5.55%	12.82%
	Oral drugs and insulin	9.91%	22.86%	18.93%
Use of RAS inhibitor		14.15%	38.35%	55.07%
Use of statins		10.49%	36.38%	44.57%
Any diabetic retinopathy		4.26%	33.10%	35.00%
Sensory neuropathy		0.24%	2.24%	4.39%
Microalbuminuria		3.49%	30.53%	29.44%
Macroalbuminuria		0.27%	17.21%	25.00%
History of cancer		5.66%	5.46%	4.02%
History of coronary heart disease		0.71%	1.33%	51.46%
History of heart failure		0.24%	0.82%	10.49%
History of stroke		0.47%	0.99%	39.63%
History of peripheral vascular disease		0.00%	0.86%	9.27%
History of cardiovascular disease		1.18%	3.10%	89.39%
History of end stage renal disease		0.24%	0.64%	7.32%
History of chronic kidney disease		5.90%	19.39%	39.63%
Any history of complications		12.74%	25.80%	97.80%
HBA1c<7%		74.76%	29.96%	35.94%

BP<130/80 mmHg		75.65%	31.64%	30.24%
LDL-C<2.6 mmol/L		56.45%	34.88%	60.96%
Number of ABC targets attained	0	0.71%	31.26%	17.80%
	1	19.10%	44.63%	44.88%
	2	55.42%	21.15%	30.37%
	3	24.76%	2.97%	6.95%

Table 6 summarises the distribution of risk factors and complications according to the JADE risk category which divided patients into:

1. very high risk (4) with established cardiovascular complications and/or ESRD;
2. high risk (3) without clinically-evident cardiovascular-renal complications but harbour chronic kidney disease and/or 3 or more cardiometabolic risk factors and/or microvascular complications and/or insulin treatment
3. medium to low risk (1-2) without complications and few risk factors and treated with oral drugs.

Over 60% of these middle-aged patients belong to risk category 3 with a predicted annual event rate of 5% [35]. Despite their high risk profile for future events, the attainment rates of multiple targets were only half (3%) of that in the very high risk group with complications (7%) who had high motivation to adhere to treatment with the development of organ damage. These findings highlighted the challenges in motivating patients to adhere to complex treatment regimen, change lifestyle or perform regular self monitoring of blood glucose prior to development of complications. Paradoxically, it is before the occurrence of complications that preventive measures will have its greatest impacts and benefits [36].

Table 7 Incidence of major events in type 2 diabetic patients managed in 3 care settings expressed as rate per 1000 patient-years stratified by the JADE risk categories.

	Risk Level	CHD	CVA	CVD	CHF	CKD	ESRD	Cancer	Death	any event
HA	1-2	0.72	1.43	2.17	0.00	40.66	0.71	3.00	2.83	60.35
HA-JADE	1-2	3.72	1.55	5.32	0.31	27.94	1.23	4.56	4.62	43.24
PPP-JADE	1-2	2.76	0.61	2.78	0.91	16.19	0.61	3.73	1.21	27.13
HA	3	6.27	6.53	14.15	3.17	84.47	13.94	7.24	12.41	173.94
HA-JADE	3	8.47	4.95	13.89	3.82	68.66	11.72	8.31	11.81	154.66
PPP-JADE	3	6.23	4.04	10.73	2.26	37.87	5.50	7.10	6.55	79.67
HA	4	21.41	10.52	54.62	14.27	144.42	30.98	6.52	31.38	433.10
HA-JADE	4	14.11	10.95	32.37	11.92	135.11	34.28	9.01	39.77	443.21
PPP-JADE	4	7.16	11.04	31.25	11.08	114.25	22.67	8.56	26.36	311.64

Table 7 summarizes the increasing rates of all 7 critical illnesses including death with increasing JADE risk categories ranging from 3% per year in the low risk group to over 40% per year in the very high risk group. Yet within each risk category, there was substantial reduction in event rates amongst patients receiving the JADE-enhanced care, with the lowest rate observed in those receiving PPP-JADE care. These findings lent support to the proposition that a fully integrated care model supported by a stable doctor-nurse team with periodic assessment and empowerment can bring out the best of medical technologies and clinical expertise with improved clinical outcomes.

Table 8: Cox regression analysis of hazard ratio (HR) with 95% confidence intervals (lower and upper bound) of independent predictors for first clinical event with adjustment for confounders in type 2 diabetes.

	All cancer				Death				Any event			
		Lower	Upper	P		Lower	Upper	P		Lower	Upper	P
HA-JADE	1.178	0.900	1.542	0.233	1.032	0.863	1.233	0.730	0.829	0.780	0.882	0.000
PPP-JADE	1.004	0.739	1.365	0.978	0.619	0.494	0.775	0.000	0.508	0.469	0.549	0.000
Age of diagnosis	1.003	0.991	1.015	0.679	0.982	0.975	0.989	0.000	0.983	0.980	0.986	0.000
Male gender	1.192	0.980	1.450	0.078	1.417	1.236	1.625	0.000	1.145	1.090	1.203	0.000
Risk level 3	1.543	1.046	2.277	0.029	2.252	1.460	3.472	0.000	2.254	1.994	2.548	0.000
Risk level 4	1.304	0.837	2.033	0.240	4.488	2.880	6.993	0.000	4.325	3.801	4.922	0.000
College education	0.723	0.496	1.056	0.093	0.668	0.500	0.892	0.006	0.747	0.683	0.818	0.000
Use of RAS inhibitor	1.103	0.901	1.350	0.343	1.029	0.895	1.183	0.687	1.615	1.535	1.699	0.000
Use of statins	0.764	0.619	0.944	0.012	0.859	0.745	0.991	0.037	1.027	0.975	1.081	0.323

Table 9 *Cox regression analysis of hazard ratio (HR) with 95% confidence intervals (lower and upper bound) of independent predictors for first clinical event with adjustment for confounders in type 2 diabetes.*

	CKD				ESRD				CVD			
		Lower	Upper	P		Lower	Upper	P		Lower	Upper	P
HA-JADE	0.755	0.688	0.828	0.000	0.803	0.670	0.962	0.018	0.943	0.756	1.175	0.598
PPP-JADE	0.491	0.437	0.553	0.000	0.489	0.385	0.621	0.000	0.758	0.584	0.984	0.037
Age of diagnosis	0.988	0.984	0.993	0.000	0.965	0.957	0.972	0.000	0.975	0.966	0.985	0.000
Male gender	1.104	1.023	1.192	0.011	1.328	1.149	1.535	0.000	1.683	1.418	1.997	0.000
Risk level 3	1.755	1.500	2.052	0.000	6.573	3.104	13.917	0.000	2.305	1.575	3.374	0.000
Risk level 4	2.515	2.116	2.989	0.000	11.631	5.447	24.834	0.000	4.911	2.951	8.173	0.000
College education	0.883	0.774	1.007	0.063	0.464	0.329	0.654	0.000	0.816	0.602	1.107	0.192
Use of RAS inhibitor	1.544	1.428	1.670	0.000	1.400	1.200	1.632	0.000	1.273	1.070	1.514	0.006
Use of statins	0.961	0.886	1.042	0.336	1.295	1.110	1.511	0.001	0.985	0.826	1.175	0.868

Using the HA model as the referent, patients receiving HA-JADE or PPP-JADE had 20-50% reduction in all clinical events including cardiovascular-renal disease, cancer and death even after adjustment for other confounders. Other risk factors predictive of clinical events included young age of diagnosis (thus long disease duration), JADE risk categories (3 and 4) and male gender while college education was protective. The association of RAS inhibitors with clinical events was likely to be confounded by reverse causality with cardiovascular-renal disease while the use of statins was associated with reduced risk of major events including cancer and death.

Table 10 Cox regression analysis of relative risks (RR) of predictors for first event of hospitalization with adjustment for confounders in type 2 diabetes.

	RR	lower	Upper	P	RR	lower	Upper	P	RR	lower	Upper	P	RR	lower	Upper	P
HA-JADE	1.135	0.968	1.331	0.120	1.117	0.952	1.310	0.175	1.118	0.953	1.311	0.172	1.122	0.952	1.323	0.169
PPP-JADE	0.698	0.587	0.830	0.000	0.710	0.596	0.844	0.000	0.723	0.607	0.861	0.000	0.723	0.604	0.865	0.000
Age of diagnosis	0.987	0.980	0.993	0.000	0.988	0.982	0.995	0.001	0.988	0.982	0.995	0.000	0.991	0.984	0.998	0.008
Male gender	1.108	1.002	1.226	0.046	1.086	0.981	1.202	0.112	1.104	0.996	1.222	0.059	1.089	0.981	1.210	0.110
Risk level 3					1.432	1.219	1.682	0.000	1.419	1.207	1.667	0.000	1.332	1.121	1.582	0.001
Risk level 4					2.101	1.687	2.617	0.000	2.109	1.693	2.626	0.000	1.944	1.541	2.453	0.000
College education									0.846	0.723	0.989	0.036	0.886	0.754	1.041	0.140
Use of RAS inhibitors													1.333	1.196	1.486	0.000
Use of statins													0.878	0.787	0.981	0.022

Using the HA model as the referent and after adjustment for confounders, patients receiving PPP-JADE care had 30% risk reduction in being hospitalized. Other risk factors predictive of first hospitalization episode included young age of diagnosis while college education was protective. The association of RAS inhibitors with hospitalization was likely to be confounded by reverse causality with cardiovascular-renal disease while the use of statins was consistently associated with reduced risk of hospitalization.

Table 11 Negative binomial analysis of relative risks (RR) for hospitalization nights after adjustment for confounders in type 2 diabetes.

	RR	lower	Upper	P	RR	lower	Upper	P	RR	lower	Upper	P	RR	lower	Upper	P
(Intercept)	1.242	1.007	1.535	0.063	0.465	0.365	0.593	0.000	0.535	0.419	0.685	0.000	0.563	0.439	0.724	0.000
HA-JADE	0.947	0.841	1.065	0.365	0.893	0.795	1.002	0.054	0.912	0.812	1.023	0.116	0.908	0.807	1.021	0.105
PPP-JADE	0.463	0.401	0.535	0.000	0.471	0.409	0.543	0.000	0.500	0.433	0.576	0.000	0.528	0.455	0.612	0.000
Age of diagnosis	1.022	1.019	1.026	0.000	1.019	1.015	1.022	0.000	1.018	1.015	1.022	0.000	1.018	1.015	1.022	0.000
Male gender	1.053	0.959	1.156	0.277	0.995	0.908	1.090	0.911	1.029	0.938	1.128	0.542	1.032	0.941	1.133	0.499
Risk level 3					2.790	2.406	3.221	0.000	2.483	2.134	2.877	0.000	2.249	1.914	2.630	0.000
Risk level 4					6.499	5.497	7.663	0.000	5.770	4.865	6.827	0.000	5.288	4.408	6.328	0.000
College education									0.552	0.476	0.642	0.000	0.548	0.472	0.641	0.000
Use of RAS inhibitor													1.274	1.156	1.405	0.000
Use of statins													0.839	0.760	0.926	0.001

Using the HA model as the referent and after adjustment for confounders, patients receiving PPP-JADE care had 50% risk reduction in the number of hospitalization nights. Other risk factors predictive of duration of hospital stay included old age of diagnosis while college education was protective. The association of RAS inhibitors with hospitalization was likely to be confounded by reverse causality with cardiovascular-renal disease while the use of statins was associated with reduced risk of duration of hospital stay.

Table 12 Estimated annual cost savings due to prevention of hospitalization with the implementation of the JADE Program in the private and public settings in 400,000 type 2 diabetic patients stratified by their risk profiles.

	Risk level	night/year	%	Estimated no of patients*	Estimated HA cost per year	Total HA saving using PPP-JADE	Saving per patient
HA	1-2	1.572	11.76%	47,036	320,162,763		
HA-JADE	1-2	1.233	11.76%	47,036	251,120,030	-69,042,733	-1,468
PPP-JADE	1-2	0.386	11.76%	47,036	78,615,030	-241,547,734	-5,135
HA	3	3.492	66.22%	264,891	4,005,247,281		
HA-JADE	3	2.970	66.22%	264,891	3,406,524,749	-598,722,532	-2,260
PPP-JADE	3	1.785	66.22%	264,891	2,047,355,784	-1,957,891,497	-7,391
HA	4	7.673	22.02%	88,073	2,926,145,279		
HA-JADE	4	7.456	22.02%	88,073	2,843,391,007	-82,754,272	-939
PPP-JADE	4	4.910	22.02%	88,073	1,872,458,402	-1,053,686,877	-11,964

**Assuming 400,000 patients with type 2 diabetes are under HA care with the cost of each hospital night at HKD 4330*

The majority of HA patients with diabetes have multiple risk factors and complications with frequent use of hospital resources. Based on a population of 400,000 adults with diabetes managed in the HA setting, the implementation of the JADE Program in the public setting by integrating the HA-CMS and JADE system can save HA expenditures of HKD 750,519,537 (HKD 1,876 /patient/year) which represents 1.35% of HA annual budget. By contracting private doctors and diabetes centres to implement JADE Program using PPP, HA can save HKD 3,253,126,108 (HKD 8,133 /patient/year) which represents 6% of the annual HA budget. Since over 60% of HA patients belong to risk level 3, if we first target these patients, HA can save up to HKD 1,958 million within 1 year due to hospitalization alone. If no action is taken, the HA budget is expected to increase by 8% yearly (HKD 2,700 million in 2015), most of which are due to avoidable hospitalizations.

2.8. Development of Diabetes Outcome Model

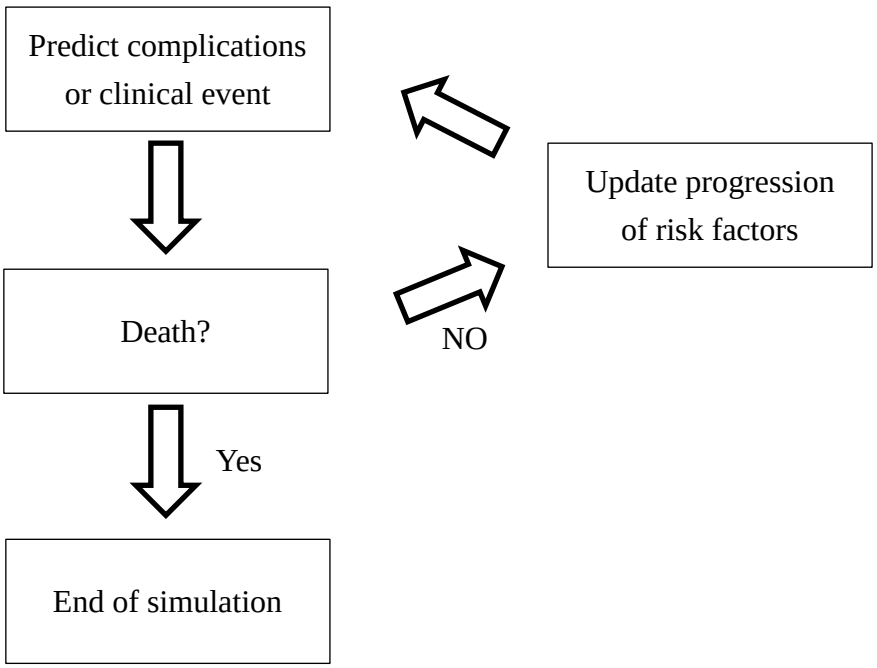
The United Kingdom Prospective Diabetes Study (UKPDS) was a landmark multicenter trial involving 5,102 newly diagnosed type 2 diabetic patients recruited from 23 clinical sites between 1977 and 1997, randomized to receive either intensified treatment or usual care. After a median follow-up period of 10 years, lowering HbA1c to 7.0% in the intensified treatment group versus 7.9% in the usual care group reduced the risk of 'any diabetes-related endpoint' by 12% and microvascular disease by 25%, with a 16% trend towards reduced risk of myocardial infarction (P=0.052). These benefits became significant in the 10-year post-trial period for both cardiovascular disease and all-cause death, confirming the long term benefits of early control of glycemia [37]. In a subgroup of 1,148 hypertensive patients, reducing blood pressure to 142/82 mmHg versus 154/87 mmHg reduced the risk of both microvascular and macrovascular disease with additive benefits between the control of blood pressure and HbA1c on cardiovascular-renal events [38].

2.9. Simulation models of diabetic complications

Using this prospective database, researchers developed the UKPDS model [39] to simulate the probabilities of occurrence of different clinical events during a lifetime. These simulation models usually contain two parts. The first part is the estimation of probability of new clinical events based on interactive effects between risk factors and pre-existing complications. The second part is the progression of risk factors which are subject to modification for changing the clinical course. Some factors are constant, such as gender. Some are deterministic whose changes with time are known, e.g. age based on date of birth and disease duration based on time of diagnosis. Other factors, e.g. changes in blood glucose, blood pressure and blood lipids, can vary with time depending on patients' attributes (gender, age, disease duration), treatments (usual versus intensified treatment), baseline levels, use of medications, care settings and other modulating factors, e.g. obesity and smoking.

Typically, the simulation goes through the first part and second part repeatedly as shown in Figure 6. Each cycle represents a fixed time frame, e.g. one year. The first part determines the probability of occurrence of an event and the second part predicts the progression of risk factors. The updated risk factors will be used to predict future events in the next time frame. The simulation stops after a fixed number of cycles or until all patients have died.

Figure 6 A simplified structure of a simulation model of diabetes complications



2.10. The discrete-time Markov model

Many simulation models of diabetes complications including the UKPDS model [39] are discrete-time Markov models which predict the status of a patient within a specific time unit with omission of details between these time units. For example, the probability of CHD in a particular year is predicted but not a particular month or time within the year. Although discrete-time and Markov property have potential limitations, they are more akin to real world data which are often random due to different follow up intervals and changes in doctors or health care institutions. In sum, each type of diabetes-related event is modelled using one or more equations that include time-varying risk factors. Weibull proportional hazards regression is then used to model the occurrence of a composite outcome covering both fatal and non-fatal events.

2.11. The Monte-Carlo simulation

The Monte-Carlo simulation is a computational method based on repeated sampling of random numbers. It is a numerical method which aims to derive an approximate rather than exact solution. This method can be used together with the discrete-time Markov model to increase the accuracy of the predictions [40]. Here, random numbers are used to determine the uncertain part in the model. For example, the probability of CHD in a year is 5%. A

random number between 0 and 1 is drawn at year 1. If the random number is <0.05 (5%), then the prediction is accepted since it falls within the estimated probability and the model will proceed along the path as if the patient had developed a CHD. If the random number is ≥0.05, then the prediction is not accepted since the number is above the estimated probability and the model will proceed along the alternative path that the patient had not developed CHD. In year 2, based on the progression of risk factors, the probability of CHD will be estimated with sampling of random number to determine whether the event has occurred or the model will repeat itself for the following years until the event occurs. For the same patient, the model will run a series of simulation, typically over 1000 times, to give a probability of time to a particular event for cost estimation and performance of other calculations.

3. Chinese Diabetes Outcome Model (CDOM)

Using a method similar to the UKPDS [39], we used data from 9,506 patients with type 2 diabetes enrolled in the HKDR between 1995 and 2007 to develop the CDOM with clinical endpoints censored in 2009 using the ICD 9th Revision (ICD-9) retrieved from the HA-CMS including death status from the Hong Kong Death Registry (Table 13).

Table 13 Definitions of critical illnesses using International Classification of Diseases (ICD) Code.

Events	Diagnosis	ICD-9 code
Coronary heart disease	myocardial infarction	410
	ischemic heart disease	411-414
	coronary heart disease or death	410-414
Congestive heart failure	non-fatal and fatal heart failure	428
Stroke	non-fatal ischemic stroke	432-434, 436
	fatal ischemic stroke	432-438
hemorrhagic stroke	fatal/ non-fatal subarachnoid hemorrhage	430
	intracerebral hemorrhage	431
	other/unspecified intracranial hemorrhage	432

Peripheral vascular disease	peripheral circulatory disorders	250.7
	peripheral vascular disease	440.2, 440.4, 443.9
	gangrene	785.4
	angiopathy in diseases classified elsewhere	443.81
	peripheral vascular disease unspecified	443.9
	peripheral vascular shunt or bypass	39.29
	insertion of non-drug-eluting peripheral vessel stents	39.90
	amputation of lower limb without a traumatic amputation diagnosis code	84.1 895-897
Chronic kidney disease	Estimated GFR<60 ml/min/1.73 m^2	
End-stage renal disease	Estimated GFR<15 ml/min per/1.73 m^2	
	first hospital discharge diagnosis of renal manifestation with renal failure	250.4
	fatal or non-fatal renal failure	585 and 586
	requirement of dialysis	39.95 or 54.98
Cardiovascular events	coronary heart disease, congestive heart failure, stroke and peripheral vascular disease.	
Renal events	chronic kidney disease included end-stage renal disease.	

Based on the methodology of the UKPDS model, we have developed a series of risk equations to predict 7 clinical events by dividing the dataset into the training set (3/4) and testing set (1/4). The training dataset was used to develop the risk equations followed by validation in the testing set. The equations were Weibull proportional hazard models. We used easily available data based on history taking (age, disease duration, sex, smoking status, history of major illnesses) and physical examination (blood pressure, assessment of foot pulses for PVD, waist circumference) and blood tests

(HbA1c, lipids) to develop a series of equations for major clinical events. The following table summarises the independent hazard ratios, as indicators of the effect size, of these covariables on each of the clinical endpoints.

Table 14 Hazard ratios of risk factors for 7 critical illnesses in the Chinese Diabetes Outcome Model.

	CHD	PVD	Stroke	CHF	ESRD	Cancer	Death
Disease duration	1.038	1.048		1.03	1.059		1.015
Gender (Male)	1.24	1.642			1.463		1.281
Waist			1.011	1.019		1.009	
Ex-smoker	1.247		1.144			1.218	
Current smoker	1.751		1.763			1.914	
HbA1c		1.312	1.103	1.075	0.894		0.969
SBP	1.009	1.013	1.007	1.011	1.018		
HDL-C	0.706	0.455			1.733		
LDL-C	1.233						1.113
log(triglyceride)	1.214				2.125	0.707	0.686
CHD					1.34		1.193
PVD	1.62		1.582	1.58	1.606		1.494
Stroke		2.808		1.65	1.282		3.102
Heart failure	2.462		1.576		3.555		2.142
ESRD	2.671	3.242	1.844	5.155			8.491
Cancer			0.524				6.136
Weibull parameters							
scale	240.855	1005.182	175.158	212.817	497.035	122.875	116.603
shape	2.896	2.504	5.141	5.874	2.381	4.406	4.121

Table 14 highlights the heterogeneity of risk factors and complications as well as their interactions in predicting these 7 critical illnesses with good performance based on the Weibull parameters. The presence of complications markedly increased the risk of development of other complications. While men are at high risk for most of these complications, it was disease duration rather than age that had major effects on clinical outcomes. These findings highlighted the high risk nature of young patients who face long disease

duration and that early diagnosis and intervention are particularly important at a time when the clinical course is still modifiable.

The effects of smoking on risk of cardiovascular disease and cancer re-affirm the importance of its avoidance and cessation, which often requires intensive behavioural counselling and ongoing support. Reducing obesity (waist circumference), HbA1c, lipids and blood pressure can modify the outcomes. Given their independent effects, controlling multiple risk factors can have huge impacts on clinical outcomes as previously reported by our groups in randomized trials and quality improvement programs [41].

Unlike the UKPDS where patients returned for regular follow up with measurements of clinical and laboratory data, the measurement of follow up data at the HA clinic visits are more random. While blood pressure and waist circumference were not usually captured by the HA-CMS, laboratory results of HbA1c and lipids during clinic visits could be retrieved. We used linear random-effects model to develop equations for estimating the yearly changes in HbA1c and lipid values during the observational period, adjusted for co-variables including age and duration of diabetes. We then used this equation to estimate the next HbA1c or lipid values in 1 year time which was then used to predict the clinical endpoints.

- e.g. (HbA1c at t=1) = Age+duration+sex+HbA1c at t=0

Having developed these 2 sets of equations for predicting clinical outcomes and time-varying risk factors, we performed 100 stimulations for each patient to estimate the time to the first event until the time of death. Using these simulations, we have computed a series of outcome models over a 15-year period. The probability of all clinical events, except death, lies within the 95% confidence intervals of the observed event rate.

In the case of death, there was a tendency of underestimation although the deviation was only minor. We then used data from the JADE Registry collected from 2007 through to 2015 including 12,940 patients to validate the CDOM. The model tended to overestimate the events in part due to improvement of risk factors and increased use of organ-protective drugs over time, although the deviation was just outside the confidence intervals.

Next, we simulated 2 models to estimate the number of events in 400,000 diabetic patients with profiles typical of a patient attending the HA clinics over a 15-year period managed by the HA or PPP-JADE care models. We used 15-year period as a cutoff since the mean follow-up period of the original cohort was only 10 years for the HKDR and 3.7 years for the JADE cohort

The following table summarises the total number of events in these 400,000 patients over a 15-year period in 2 care settings using hazard ratios ranging from 0.489 to 1.004 as estimated in our Cox regression model (Table 8; Table 9). As an example, we also showed the number of events in 3 simulations (S1-3) although for each of these settings, 100 simulations were performed for each patient to give a range of probabilities of time to first clinical event.

Table 15 Using the Chinese Diabetes Outcome Model to simulate the number of events in 400,000 Chinese type 2 diabetic patients managed in usual HA or PPP-JADE settings, with 100 simulations for each patient till death. S1-S3 are examples of simulation models with estimated number of events in different settings.

	HA care	**PPP-JADE**	**HA care**	**PPP-JADE**	**HA care**	**PPP-JADE**	**HA care**	**PPP-JADE**
	Mean	Mean	S1	S1	S2	S2	S3	S3
CHD	58504.79	51968.05	59681	56613	57764	50735	59681	52524
PVD	16347.60	9847.92	16358	10990	17252	8946	15847	11629
Stroke	52490.73	39798.08	55080	39617	53163	41789	52396	41022
Heart failure	55932.27	41409.58	56613	44345	57508	41406	55208	43578
ESRD	81837.70	47432.59	83067	47029	82556	48051	83706	49840
Cancer	51799.36	56645.37	55208	53035	50990	56997	53546	55208
Deaths	141298.40	93501.60	144409	91502	139936	95208	141470	87412

CHD=coronary heart disease; PVD=peripheral vascular disease; ESRD=end stage renal disease

These simulation models estimated the cumulative number of critical illness in 400,000 type 2 diabetic patients attending the HA setting. These patients are in their fifties with 8 years of disease duration, harbouring multiple risk factors and complications with low levels of attainment of multiple treatment targets and doubtful treatment adherence. By implementing the JADE program, especially if further enhanced by a stable doctor-patient relationship, supported by a Diabetes Centre through PPP, we can substantially reduce the number of all events. The slight increase in cancer rates in the PPP-JADE program may be due to increased life expectancy in patients compared to those receiving HA care. However, the overall benefits are in favour of the PPP-JADE program due to the large number of cardiovascular-renal events prevented.

Figures 7-10 show the cumulative number of events in these 2 settings over a 15-year period stratified by the JADE risk categories. For all 3 categories (low, high, very high risk), the cumulative events were estimated to be 40%, 50% and 60% respectively in the HA care setting with approximately 20% risk reduction in all 3 groups receiving the PPP-JADE program through the YCK Centre. Despite similar relative risk reduction, due to the large number of events in the high (risk level 3) and very high risk groups (risk level 4), the impacts of the PPP-JADE program will be greatest in these patients with the highest number of prevented events.

Figure 7 The estimated cumulative incidence over a 15-year period for any events in patients receiving usual HA care versus PPP-JADE care through the YCK Centre and stratified by various risk categories.

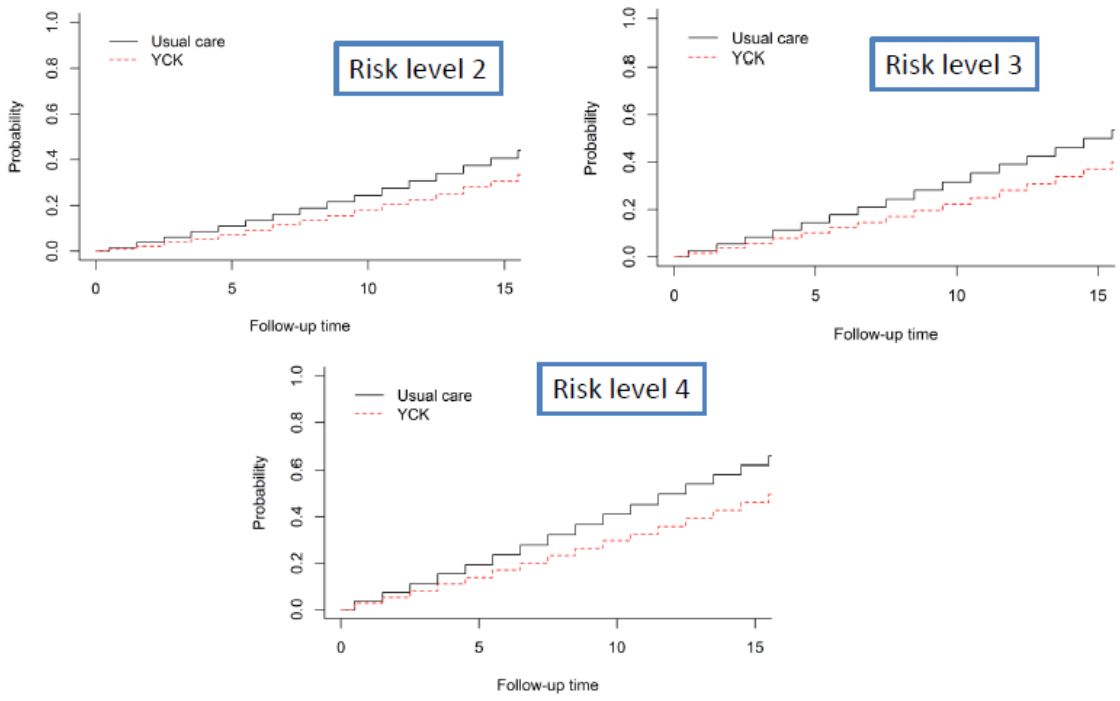


Figure 8 The estimated incidence over a 15-year period for all-cause death in patients receiving usual HA care versus PPP-JADE care through the YCK Centre and stratified by various risk categories.

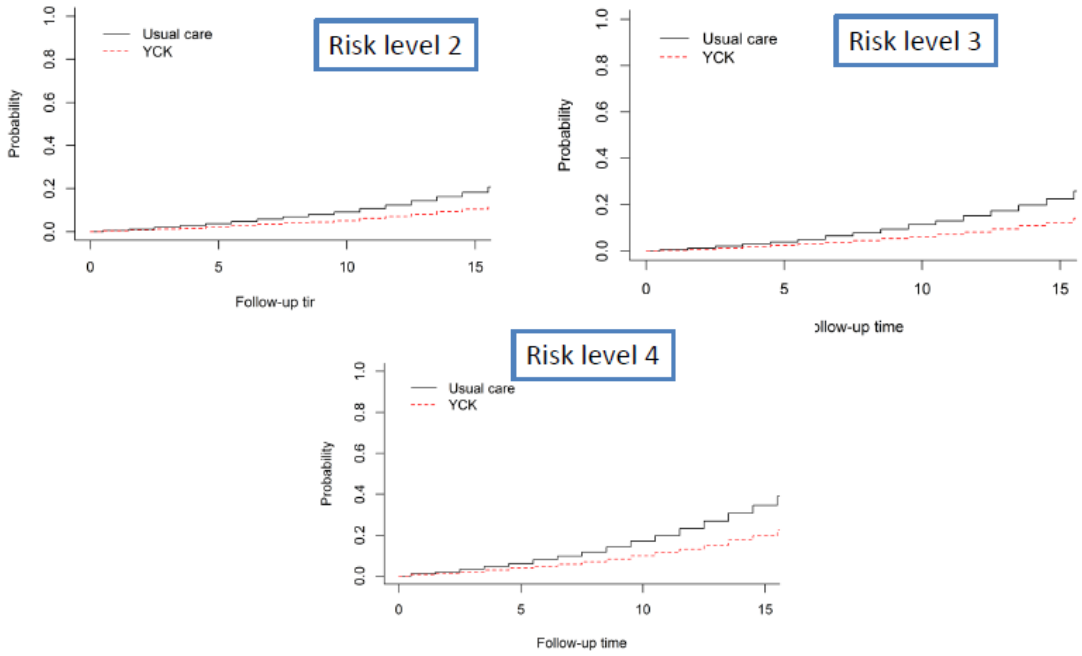


Figure 9 The estimated incidence over a 15-year period for end stage renal disease in patients receiving usual HA care and PPP-JADE care through the YCK Centre and stratified by various risk categories.

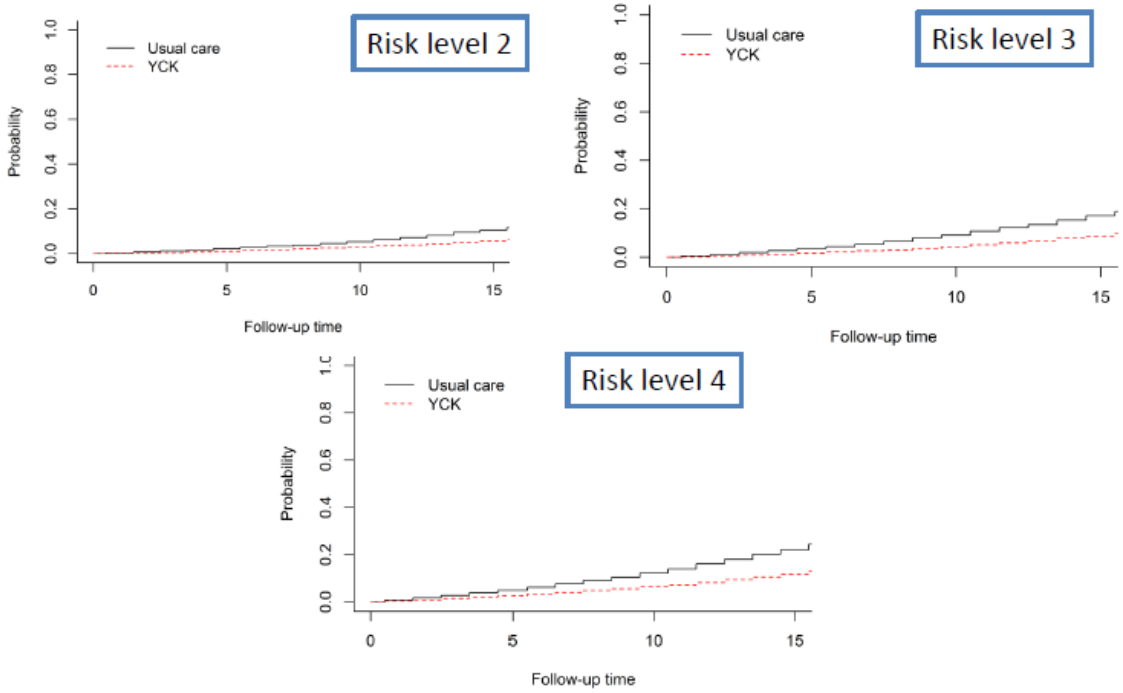


Figure 10 The estimated incidence over a 15-year period for coronary heart disease in patients receiving usual HA care and PPP-JADE care through the YCK Centre and stratified by various risk categories.

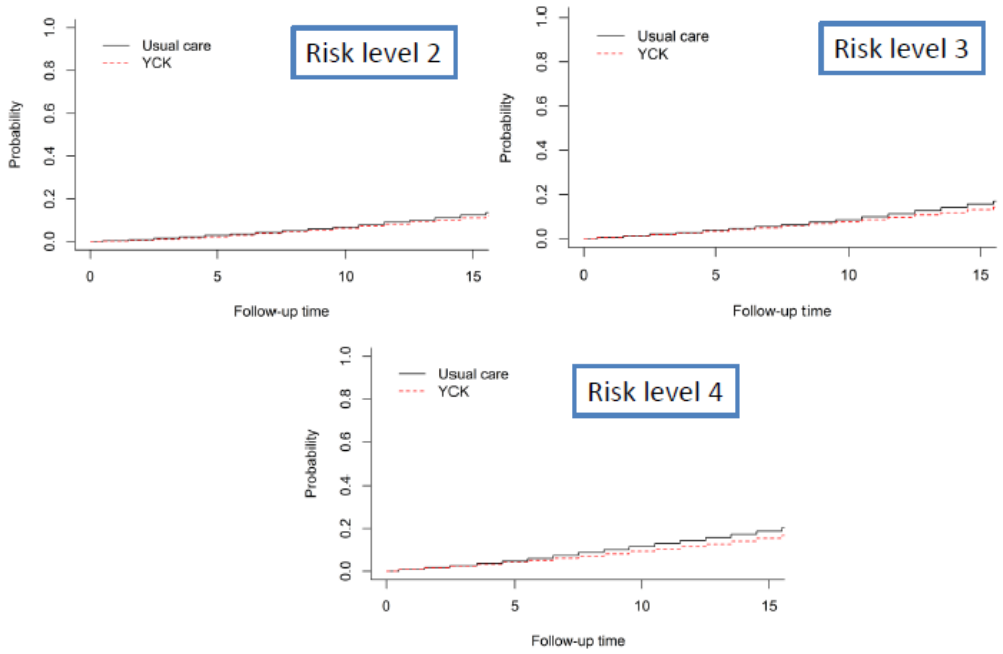
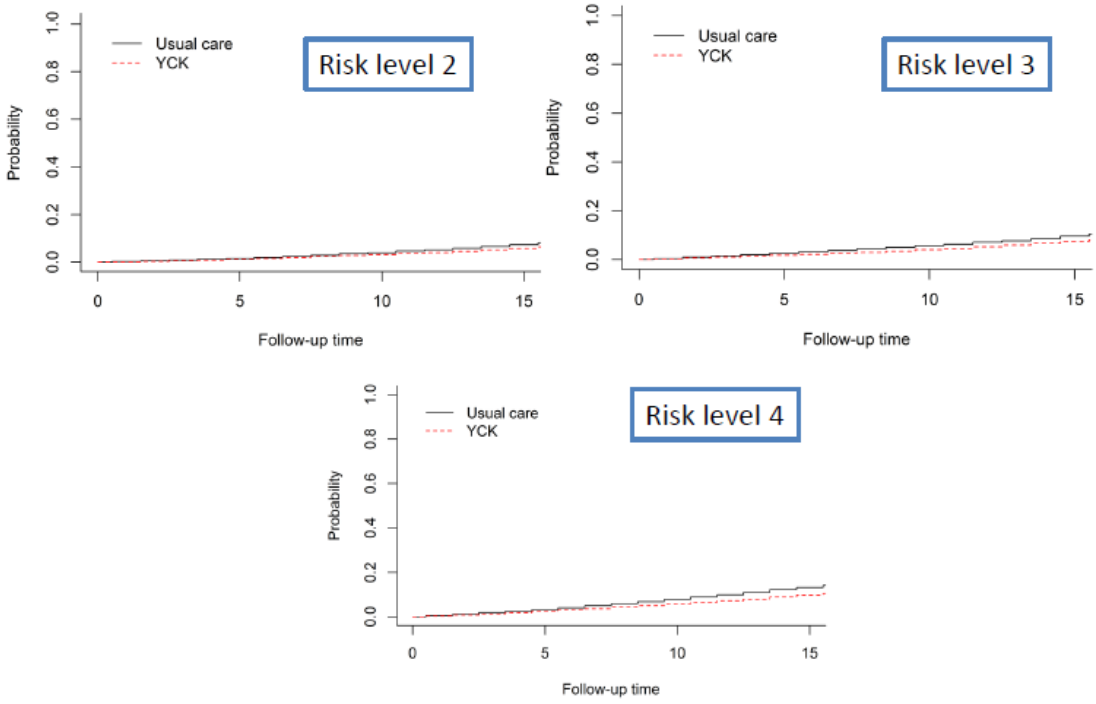


Figure 11 The estimated incidence over a 15-year period for stroke in patients receiving usual HA care and PPP-JADE care through the YCK Centre and stratified by various risk categories.



3.1. Sensitivity analysis – randomization using simulation models

In a sensitivity analysis, using a methodology modified from the UKPDS [39], we developed 2 simulation models using data from patients managed by the 1) JADE Program implemented through YCK Centre and PWH (n=5622) as a JADE model and 2) a non-JADE model in the usual HA setting (n=10,136) using R (version 3.3.2). In the HA cohort, the mean age was 63 years with a mean disease duration of 5.9 years and mean follow up period of 4 years (2000-2012). In the JADE cohort, the mean age was 57 years with a mean disease duration of 9 years and mean follow period of 5 years (2007- 2015).

We first used 3/4 of the HA cohort to develop 1) equations for predicting time-varying risk factors (HbA1c and lipids) at yearly intervals and 2) parametric survival and logistic regression models to estimate the interactive effects of these risk factors and complications on fatal and non-fatal clinical endpoints until death. The risk factors included age, sex, disease duration, history of prior stroke, myocardial infarction (MI), cancer and ESRD, lipids and HbA1c values at baseline and prior to the incident event. The HA model was then used to predict the outcomes of the remaining 1/4 of patients for validation purpose. The predicted event rates of MI, stroke and ESRD fell within 95% confidence intervals of the observed rates.

We then used the JADE cohort to develop a set of equations for time-varying risk factors in addition to that from the HA cohort. Mimicking a randomized study design and using the original HA cohort, we simulated 2 dynamic models using the risk equations developed from the HA and JADE cohorts. Based on 50 simulations of each of the two trial arms, the total number of MI, stroke and ESRD were reduced by 20.42%, 18.38% and 10.59% respectively in the JADE setting as compared to the HA setting. The differences in the event rates between the 2 care models were mainly due to differences in the progression of modifiable risk factors which impacted about development of complications, the latter then interacted with secular changes in risk factors to influence development of other outcomes.

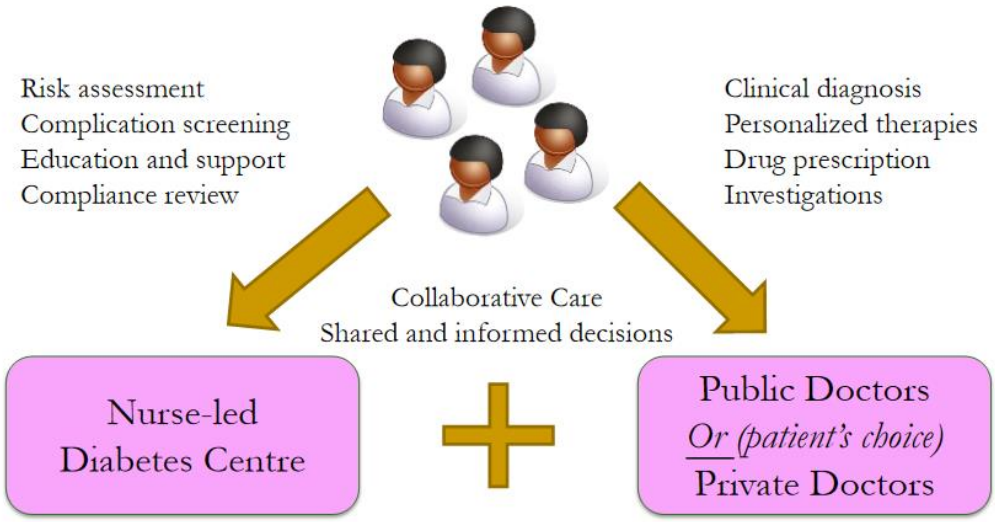


Figure 12 A schematic diagram summarizing the use of a doctor-nurse team to deliver the JADE Program implemented through the Diabetes Centre including risk assessment, education and ongoing support which enable doctors to formulate personalized treatment with shared and informed decisions between patients and the care team.

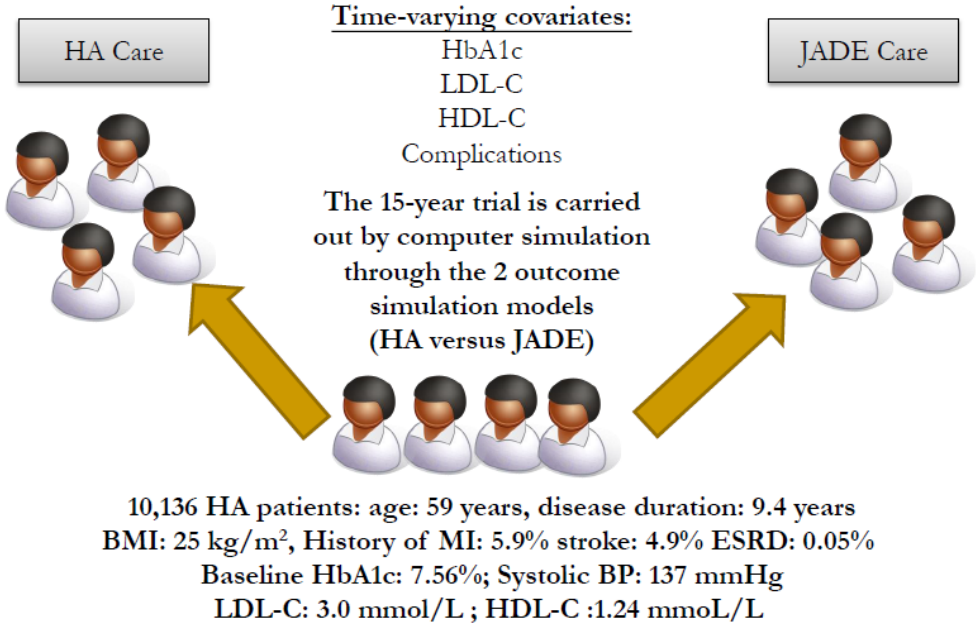


Figure 13 Using the JADE simulation model as the intervention arm and HA model as the control arm, we simulated the outcome of 10,136 type 2 diabetic patients with typical features of those attending the HA setting and estimated the number of events during a 15-year period.

Table 16 The cumulative number of clinical events in 10,136 type 2 diabetic patients followed up in the HA or JADE settings. A total of 50 simulations were performed for each patient to estimate the probabilities of developing a critical illness till death. The results of 8 of these simulations (S1-S8) were also shown.

	Mean	S1	S2	S3	S4	S5	S6	S7	S8
HA model									
MI	270.24	252	299	269	274	246	260	279	223
Stroke	511.72	467	505	487	487	524	514	508	500
ESRD	530.94	516	549	496	531	508	535	539	492
Death	2221.02	2179	2276	2200	2194	2134	2238	2236	2167
JADE model									
MI	215.06	232	190	202	210	209	234	224	189
Stroke	417.68	402	408	417	415	409	427	400	418
ESRD	474.72	473	469	478	488	495	462	515	472
Death	2194.84	2155	2161	2235	2184	2194	2180	2173	2227

Table 17 The percentage and absolute differences (95% confidence intervals) in the cumulative number of clinical events between the HA and JADE models for 10,136 type 2 diabetic patients over a 15 year period. The estimated number of events prevented by the JADE model for 400,000 type 2 diabetic patients managed in HA setting was shown

	Mean Difference in number of events	Lower limit	Upper limit	Percentage reduction in events	Number of events prevented in 400,000 patients over a 15-year period
MI	-55.18	-61.1215	-49.14	-20.42%	-2890
Stroke	-94.04	-101.862	-86.34	-18.38%	-4942
ESRD	-56.22	-64.466	-47.3385	-10.59%	-2954
Death	-26.18	-39.9295	-11.1375	-1.18%	-1376

MI: myocardial infarction; ESRD: end stage renal disease

3.2. Economic analysis

3.2.1. Myocardial infarction

In a local retrospective study, 95 patients were randomly drawn from 409 patients with acute MI admitted to a major public hospital in 2000. The cost components included medications, procedures, hospital stays, laboratory tests, outpatient clinic visits and other auxiliary services but the costs of any stents

used were excluded. The average direct medical costs over 1 year after one episode of MI was estimated at HKD 72,719 in 2000-2001 with a standard deviation of HKD 45,177 [42].

In an Australian study of 138 patients admitted for MI, the mean total direct cost during a 12-month period was $A20,502 in 2005, equivalent to HKD 121,084 [43]. The lower cost in Hong Kong was likely due to a smaller sample size and exclusion of the costs of coronary stents. In order to get a closer estimate to the true cost, we obtained the average of these two figures (HKD 72,719 and HKD 121,084) and adjusted the cost to HKD 96,902. Using the Consumer Price Index (CPI) which reflects the year-on-year change in price levels, we estimated the average first year treatment of MI in 2015 to be $96,902 × 0.984 × 0.97× 0.974 × 0.996 × 1.01 × 1.02 × 1.02 × 1.043 × 1.005 × 1.024 × 1.053 × 1.041 × 1.043 × 1.044, i.e. HKD 120,796.

3.2.2. Stroke

In 2006, the direct medical cost of managing a case of stroke per year was estimated to be HKD 24,452. The life expectancies for stroke survivors aged between 65 and 69 were 10.9 years and 8.0 years for men and women respectively. We used the average of these two numbers to estimate the overall life expectancy of stroke survivors aged between 65 and 69 years and estimated that the average life expectancy of a stroke patient would be (10.9 + 8.0) × 0.5 = 9.45 years. Given the disabling nature of stroke often resulting in partial dependency for the rest of the life, we estimated the direct medical cost of treating a case of stroke suffered in 2006 would be HKD 231,070 (HKD 24,452 × 9.45) [44]. Using CPI, the adjusted cost of treating a case of stroke in 2015 would be HKD231,070 × 1.02 × 1.02 × 1.043 × 1.005 × 1.024 × 1.053 × 1.041 × 1.043 × 1.044, i.e. HKD 308,004.

3.2.3. End stage renal disease (ESRD)

In Hong Kong, 82% of patients with ESRD were put on peritoneal dialysis in 2005 with the remaining 18% put on haemodialysis. The yearly cost of maintaining a patient on peritoneal dialysis was USD 13,000 and USD 30,000 for haemodialysis in 2005 [45]. In a study of 871 patients with ESRD in Singapore, the median survival time for patients receiving peritoneal dialysis was 2.5 years and that of haemodialysis group, 5 years [46]. Combining these data, the median cost of a patient with ESRD put on peritoneal dialysis in

2005 was estimated to be USD 13,000 × 2.5, i.e. USD 32,500 and that of haemodialysis, USD 30,000× 5, i.e. USD 150,000. In Hong Kong, since 82% of ESRD patients are on peritoneal dialysis and 18% on haemodialysis, the average of the median cost of treating a case of ESRD in 2005 would be USD 32,500 × 0.82 + USD 150,000 × 0.18 = USD 53,650, i.e. HKD 418,470. Using CPI to adjust the cost to level of 2015 would be HKD418,470 × 1.01 × 1.02 × 1.02 × 1.043 × 1.005 × 1.024 × 1.053 × 1.041 × 1.043 × 1.044, i.e. HKD 563,379.

3.2.4. Cost-effectiveness of Diabetes Centre and JADE Program

We used these local and international data to estimate the total treatment costs for cardiovascular-renal events in patients managed in the HA and PPP-JADE setting. Using the CDOM, we simulated the number of events prevented and costs saved in 400,000 diabetic patients managed under a JADE or HA setting over a 15-year period (Table 18). Assuming the lifetime treatment costs for one episode of CHD to be HKD 120,796; stroke, HKD 308,004 and ESRD, HKD 563,379, the prevention of these life-threatening and disabling diseases can save a HA expenditure of HKD 24,082,115,482 over a 15-year period, i.e. HKD 4,013 per patient per year. This has not included hospitalizations for other causes, work absenteeism, loss of incomes, costs due to carers and nursing home as well as human suffering.

Table 18 A summary of potential cost savings by adopting the JADE Program implemented by a doctor-nurse team supported by a Diabetes Centre through PPP over a 15 year period in 400,000 middle-aged type 2 diabetic patients with multiple risk factors simulated by the Chinese Diabetes Outcome Model .

	No of events (HA)	No of events (PPP-JADE)	No of events prevented	% reduction	Cost per event (HKD)	Total cost saving (HKD)
CHD	58,504	51,968	6,536	11.17	120,796	789,612,045
Stroke	52,490	39,798	12,692	77.64	308,004.00	3,909,386,971
ESRD	81,837	47,432	34,405	42.04	563,379	19,383,116,467
Death	141,298	93,501	47,796	33.8	Age-dependent	Age-dependent

CHD: coronary heart disease; ESRD: end stage renal disease

4. HA manpower and expenditure analysis

According to the Hong Kong – the Facts (http://www.dh.gov.hk), the following are some key figures on the health care facilities, services and providers for 7.32 million people in Hong Kong in 2015 and their comparisons

with other countries:

- In-patient services:
  - 27,895 beds in 42 HA public hospitals/institutions
  - 4,014 beds in 11 private hospitals
  - 5,498 beds in 59 nursing homes
  - 880 beds in correctional institutes
  - Bed-population ratio: 5.2 beds/1000 population as compared to
    - 2.8 (2013) in UK
    - 2.9 (2012) in USA
    - 13.3 (2013) in Korea
    - 11.0 (2013) in Japan
    - 1.9 (2013) in Malaysia
    - 3.2 (2014) in Singapore
  - 1,057,123 admissions
  - 7,584,679 patient-days
  - 7.3 days of stay
  - 3.1 hospital deaths per 1000 population
- Outpatient services
  - 47 specialist outpatient department (SOPD)
  - 73 government outpatient clinics (GOPC)
  - 7,191,780 OPD visits
  - 6,194,310 primary care visits
- Medical doctors
  - 12,981 doctors on the resident list
  - 745 on the non-resident list
  - equivalent to 1.9 /1000 population as compared to
    - 3.7 (2014) in UK
    - 3.3 (2013) in US
    - 2.3 (2012) in Japan
    - 2.6 (2013) in Korea
    - 1.0 (2013) in Malaysia
    - 3.0 (2014) in Singapore
  - Doctors working in the Department of Health: 511
  - Doctors working in the A: 5,107
- Medical charges
  - GOPC
    - HKD 45 per visit

- Specialist OPD
  - HKD 100 per visit
- Each drug item
  - HKD 10 per 3 month
- Hospital admission
  - HKD 60 upon admission
  - HKD 100/night (acute)
  - HKD 65/night (non-acute)

In the 2015 HA Report, the government subvention to HA has risen from HKD 34,366 million in 2011 to HKD 50,531 million in 2015, i.e. an average 8% annual increase (HKD 2,692 million). In this annual budget, 64% was due to staff cost and 9.6%, due to drug costs which were the top 2 expenditure items.

Table 19 The income and expenditure of the HA in year 2011-2015 in the 2015 HA Report [18].

	2015 HK$Mn 港幣百萬元	2014 HK$Mn 港幣百萬元	2013 HK$Mn 港幣百萬元	2012 HK$Mn 港幣百萬元	2011 HK$Mn 港幣百萬元
Income 收入					
Government subvention (recurrent and capital) 政府補助(經常性及資本性)	50,531	45,869	43,159	38,348	34,366
Medical fee income (net of waivers) 醫療費用收入(扣除豁免)	3,423	3,182	2,951	3,030	2,994
Non-medical fee income 非醫療費用收入	936	892	775	685	562
Designated donations 指定捐贈	230	183	149	145	143
Capital donations 資本捐贈	110	128	120	109	113
	55,230	**50,254**	**47,154**	**42,317**	**38,178**
Expenditure 支出					
Staff costs 員工成本	(37,235)	(34,459)	(32,290)	(29,616)	(26,904)
Drugs 藥物	(5,328)	(4,941)	(4,479)	(4,069)	(3,639)
Medical supplies and equipment 醫療物品及設備	(2,326)	(2,118)	(1,999)	(1,846)	(1,354)
Other operating expenses (include depreciation and amortisation) 其他營運開支(包括折舊及攤銷)	(8,964)	(8,071)	(7,288)	(6,289)	(6,039)
	(53,853)	**(49,589)**	**(46,056)**	**(41,820)**	**(37,936)**
Surplus for the Year 年度盈餘	**1,377**	**665**	**1,098**	**497**	**242**

These figures highlight the imbalance between resource allocation and use of medical workforce, with the majority of the funding spent on in-patient care in the public sector, while the majority of doctors are working in the private sector. Compared to other developed countries, Hong Kong has a higher hospital: population ratio and comparable doctor: population ratio. While HA is the main body to receive all government funding related to health care, it is not sufficient to employ all doctors in Hong Kong to provide the 'free-for-all services' to our community. This imbalance has led to a situation where the

expertise of many doctors in the private sector are not utilized while those working in the public sector are overwhelmed, rendering them unable to use their best knowledge to serve their patients.

Table 20 Cost distribution of the HA expenditure in 2015 [18].

inpatient services 住院服務	**2013-2014**	**2014-2015**
cost per inpatient discharged (HK$) 每名出院病人的成本(港元)		
general (acute and convalescent) 普通科(急症及康復)	22,610	23,830
infirmary 療養科	213,800	214,440
mentally ill 精神科	124,400	134,820
mentally handicapped 智障科	481,240	530,550
cost per patient day (HK$) 病人每日成本(港元)		
general (acute and convalescent) 普通科(急症及康復)	4,330	4,600
infirmary 療養科	1,400	1,470
mentally ill 精神科	2,270	2,470
mentally handicapped 智障科	1,290	1,400

The cost of HA service is distributed more or less equally between inpatient (54.7%) and ambulatory/outreach services (45.3%) with an average of HKD 3,000 per citizen. The majority of outpatient care is used by patients with chronic disease which are the main drivers for hospitalization, if not diagnosed, managed or controlled. Until this imbalance in workforce and resource allocation between the private and public sectors are addressed, there will be long clinic waiting list with delayed diagnosis and suboptimal ambulatory care with variable care standards with socio-economical consequences.

Table 21 HA Cost for in-patient service in 2013-2015 [18].

	2013-14	**2014-15**
Cost of services 服務成本		
cost distribution 成本分布		
cost distribution by service types (%) 按服務類別劃分的成本分布百分率(%)		
inpatient 住院服務	54.7	54.5
ambulatory and outreach 日間及外展服務	45.3	45.5
cost by service types per 1 000 population (HK$Mn) 每千人口按服務類別劃分的服務成本(港幣百萬元)		
inpatient 住院服務	3.6	3.9
ambulatory and outreach 日間及外展服務	3.0	3.2
cost of services for persons aged 65 or above 65歲或以上人士的服務成本		
share of cost of services (%) 服務所佔總成本的百分率(%)	46.0	46.2
cost of services per 1 000 population (HK$Mn) 每千人口的服務成本(港幣百萬元)	21.3	22.3

The average cost for each inpatient discharged from a general ward was HKD HKD 23,830 while the cost of each outpatient clinic visit ranges from HKD 410 for GOPCs to HKD 1,130 for specialty clinics or visit to emergency room. Depending on the risk level and clinical needs, on average, a person with diabetes should be seen 2-6 times per year with regular blood tests and comprehensive assessments every 12-18 months. The average consultation visit should last 15-30 minutes depending on the case complexity and clinical condition [47]. However, in the HA setting, the average consultation time is only 5-10 minutes with some patients being seen only twice yearly. While these patients receive a large amount of medications worth thousands of dollars, less than 50% of them were taking these medications correctly and regularly resulting in considerable drug wastage and poor control of disease [11].

Thus, despite the fact that many of these drugs have been proven to save life and reduce hospitalization, without clear explanation and regular reinforcement by a professional team, these patients will not be able to benefit fully from these expensive drugs which are meant to prevent critical illness and hospitalization. This is indeed the case as suggested by the suboptimal risk factor control despite heavy use of insulin, RAS inhibitors and statins in the HA setting. This undesirable situation means ineffective use of resources at both the inpatient and outpatient settings with increasing incidences of hospitalizations, disabilities and premature death.

Table 22 The HA cost of ambulatory and outreach services in 2013-2015 [18].

ambulatory and outreach services 日間及外展服務	**2013-2014**	**2014-2015**
cost per A&E attendance (HK$) 急症室每次診症的成本(港元)	1,040	1,140
cost per specialist outpatient attendance (HK$) 專科門診每次診症的成本(港元)	1,080	1,130
cost per general outpatient attendance (HK$) 普通科門診每次診症的成本(港元)	385	410
cost per family medicine specialist clinic attendance (HK$) 家庭醫學專科門診每次診症的成本(港元)	1,010	1,100
cost per outreach visit by community nurse (HK$) 社康護士每次外展服務的成本(港	450	490
cost per psychiatric outreach attendance (HK$) 精神科外展服務每次的成本(港元)	1,350	1,440
cost per geriatric day attendance (HK$) 老人科日間醫院每次服務的成本(港元)	1,840	1,900
fee waivers ~ 收費減免 ~		
percentage of Comprehensive Social Security Assistance (CSSA) fee waiver (%) 綜合社會保障援助(綜援)收費減免百分率 (%)	20.2	19.2
percentage of non-CSSA fee waiver (%) 非綜援收費減免百分率 (%)	4.8	5.8

Since its establishment, the HA has substantially improved the health care provision to citizens in Hong Kong who now enjoy one of the longest life

expectation in the world. However, unless there is substantial injection of funds into the public system through taxation or compulsory health insurance scheme, this 'free treatment for all' is not likely to sustain.

Table 23 The distribution of manpower in HA in 2011-2015 [18].

	No. of Full-time Equivalent (FTE) Staff 2010-11 - 2014-15 [1] 等同全職人員數目 [1]				
	2010/11	2011/12	2012/13	2013/14	2014/15
Medical 醫療					
Consultant 顧問醫生	630	699	729	761	799
Senior Medical Officer/Associate Consultant 高級醫生／副顧問醫生	1,296	1,504	1,639	1,733	1,785
Medical Officer/Resident(excluding Visiting Medical Officer) 醫生／駐院醫生(不包括到訪醫生)	3,110	2,945	2,875	2,866	2,872
Visiting Medical Officer 到訪醫生	16	16	16	16	18
Intern 駐院實習醫生	280	275	280	311	401
Senior Dental Officer/Dental Officer 高級牙科醫生／牙科醫生	5	7	6	8	8
Medical Total: 醫療人員總計：	**5,337**	**5,447**	**5,546**	**5,695**	**5,884**
Nursing Total: 護理人員總計：	**20,102**	**20,901**	**21,816**	**22,759**	**23,791**
Allied Health Total: 專職醫療人員總計：	**5,618**	**5,944**	**6,302**	**6,609**	**6,888**
Care-related Support Staff Total: 護理支援人員總計：	**9,226**	**10,389**	**11,048**	**12,137**	**13,716**
Direct Patient Care Total: 直接病人護理人手總計：	**40,283**	**42,680**	**44,713**	**47,200**	**50,278**
Non-direct Patient Care Total: 非直接病人護理人手總計：	**18,235**	**18,548**	**19,501**	**20,407**	**20,015**
HA Total: 醫管局人手總計：	**58,518**	**61,228**	**64,213**	**67,607**	**70,293**

To this end, a predominantly state-subsidized health care system can lead to complex administrative procedures. On the other hand, involvement of private sector especially for disease management which is still within reach of affordability of gainfully employed people may improve efficiency, create competitions and value for money, if properly governed.

In this context, the HA manpower has increased from 58,518 in 2010/11 to 70,293 in 2014/15. The corresponding figures for doctors were 5,337 and 5,884 representing 8% of the HA workforce. With a total of 12,981 doctors on the registration list, 7,644 doctors in the private sector are in a position to contribute to high quality ambulatory care.

Given the encouraging results of our analysis of these PPP, Hong Kong is in a prime position to develop a dual track system for diabetes care so that patients

can be seen at the right setting by the right people at the right time for the right intervention to achieve the right clinical outcomes.

5. JADE Program and Community-based Diabetes Centre

Using multiple analyses in several cohorts consisting of nearly 30,000 patients followed up since 1995, we have quantified the clinical benefits and cost-saving nature of a team-based integrated care model augmented by the JADE Program, implemented through diabetes centres in both private and public settings. Even within the HA setting where regular comprehensive assessment is already available, integration of the JADE system with the HA-CMS for issuing a personalized report with decision support followed by nurse explanation can substantially reduce hospitalization rates by 20%.

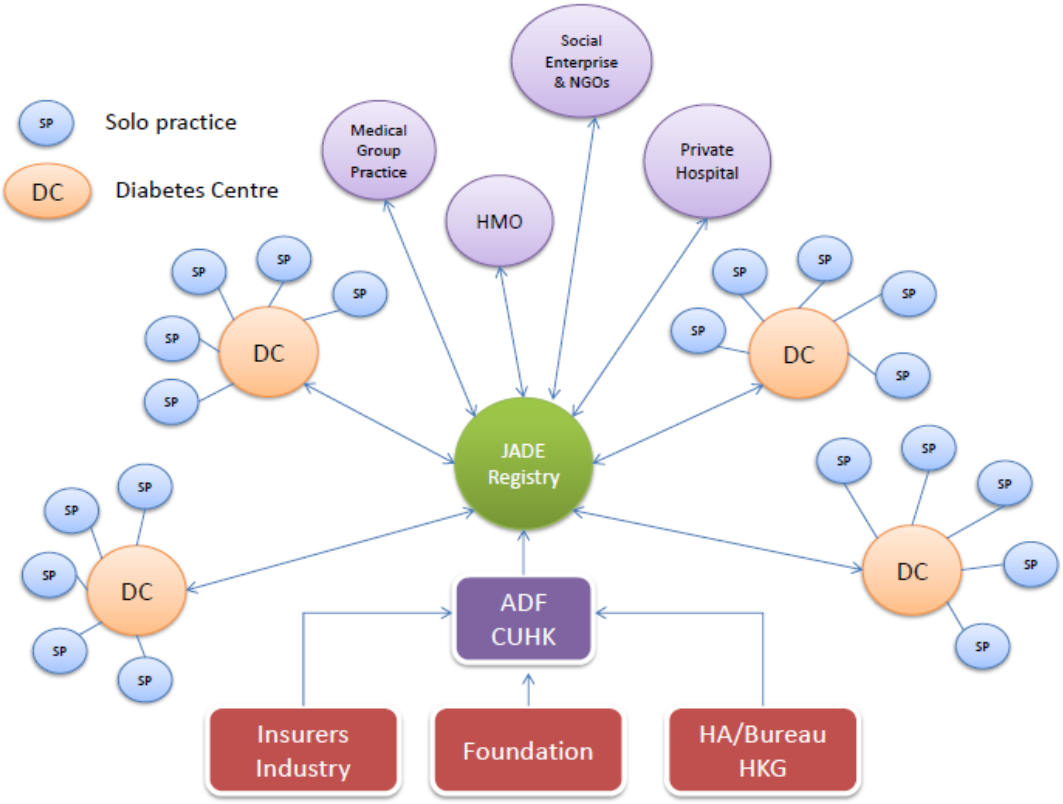


Figure 14 A sustainable private public partnership scheme where solo practices (SP) linked to community-based Diabetes Centres (DC), hospital ambulatory centres, health management organizations, medical group practices, social enterprises, non government organizations etc can use or integrate their electronic medical record system with the web-based JADE System administered by the Asia Diabetes Foundation to form a network of care providers linked by the JADE Registry to provide high quality and affordable diabetes care, partially subsidized by government, industry and foundations.

The establishment of community-based nurse-coordinated diabetes centres can share some of the tasks of doctors who can then focus on making decisions such as interpreting symptoms and signs, selecting the next lines of investigations, choosing the most appropriate treatment regimen for a particular patient at a particular time, and/or referring patients to other disciplines for investigations or management [48].

Based on the YCK model, we estimate that a team of 2-3 nurses, 2 health care assistants, 1 workman and 1 administrator can provide 10-20 comprehensive assessments per 4-hour session, i.e. 100-200 patients per week. Since these assessments are recommended every 12-24 months, these Centres will eventually establish a registry of 5,000-10,000 patients per Centre with recurrent visits. Given an estimated 700,000 diabetic patients in the community and with each centre supporting 10,000 patients, 70 centres will be needed to meet these education and assessment needs.

Currently, there are 17 hospital-based Diabetes Centres and 2-3 centres at the GOPCs in each of the 7 clusters, giving approximately 35 Diabetes Centres in the public sector. To meet these growing service demands, the private sector can be encouraged to set up another 35 Diabetes Centres, with each centre supporting 5,000-10,000 patients who can then be managed by private specialists or accredited doctors with linkage to the JADE Registry.

Ideally, each doctor can be 'contracted' to manage 30-60 patients in order to have sufficient patient volume to run mini diabetes clinic sessions with economy of scale. If 2 centres can be established in each of the 18 districts, there will be 36 centres to support 360,000 diabetic patients in the community to be managed by 6000 private doctors, i.e. 60 patients per doctor. Through this network, we will create a win-win solution with redistribution of the workforce and patient load between the public and private sectors where doctors in the public can provide quality care to a more reasonable number of patients.

5.1. Cost and return of investment of quality diabetes care

Using the HA cost as reference, depending on their risk categories, low risk patients without complications and few risk factors (JADE risk level 1-2) can be managed by family doctors every 2-3 months with a clinic visit cost of HKD

400. For high risk or very high risk patients with multiple risk factors and complications (JADE risk level 3-4), they should be reviewed by specialists or doctors with credentials every 2-3 months with a clinic visit cost of HKD 1100, assuming that the acquisition costs for drugs and laboratory tests are similar between the public and private sectors.

Based on our analysis, 65% of diabetic patients attending the HA clinics have multiple risk factors (JADE risk level 3: n=78,000) who on average spend 3.50 hospital nights per year giving a total expenditure of HKD 1,179,388,080. If these patients can be selected for management using the JADE-PPP model, the hospital nights will be reduced to 1.79 per person per year, giving a total expenditure of HKD 602,865,900, i.e. a saving of HKD 576,522,180 per year not yet counting the costs of each critical illness ranging between HKD 120,000 and HKD 500,000 and other intangible costs. By incorporating the JADE System with the HA-CMS to issue the easy-to-read personalized reports, our results suggested this can also lead to substantial HA saving.

Thus, we estimate that the annual cost for a JADE-PPP model to be HKD 10,000- 12,000 inclusive of an annual comprehensive assessment and nurse education, consultation fees for 4-6 clinic visits, essential drugs and laboratory tests. By capitalizing on the growing interest of the insurance industry to fund high quality ambulatory care, an innovative JADE diabetes care plan subsidized by the HA, Bureau and insurers can be specifically designed for our middle-aged workforce. These middle-aged patients are the most vulnerable population in need of an alternative option to the current HA care model.

In a telephone survey of over 1000 adults in Hong Kong conducted by the Asia Diabetes Foundation in 2016, only half of the interviewees were aware of the cost of a diabetes care plan. Amongst the positive responders, most of them estimated the annual treatment costs for diabetes to be HKD 10,000-20,000. When these subjects were informed that the average annual cost for outpatient diabetes care was HKD 8,000-24,000 in the private sector, most of the interviewees expressed willingness to co-pay 30-50% for a more convenient and personalized diabetes service. To this end, health economists have analyzed the willingness to pay for diabetes prevention and management program and recommended contributions from service users, insurers and government to sustain these programs [49, 50].

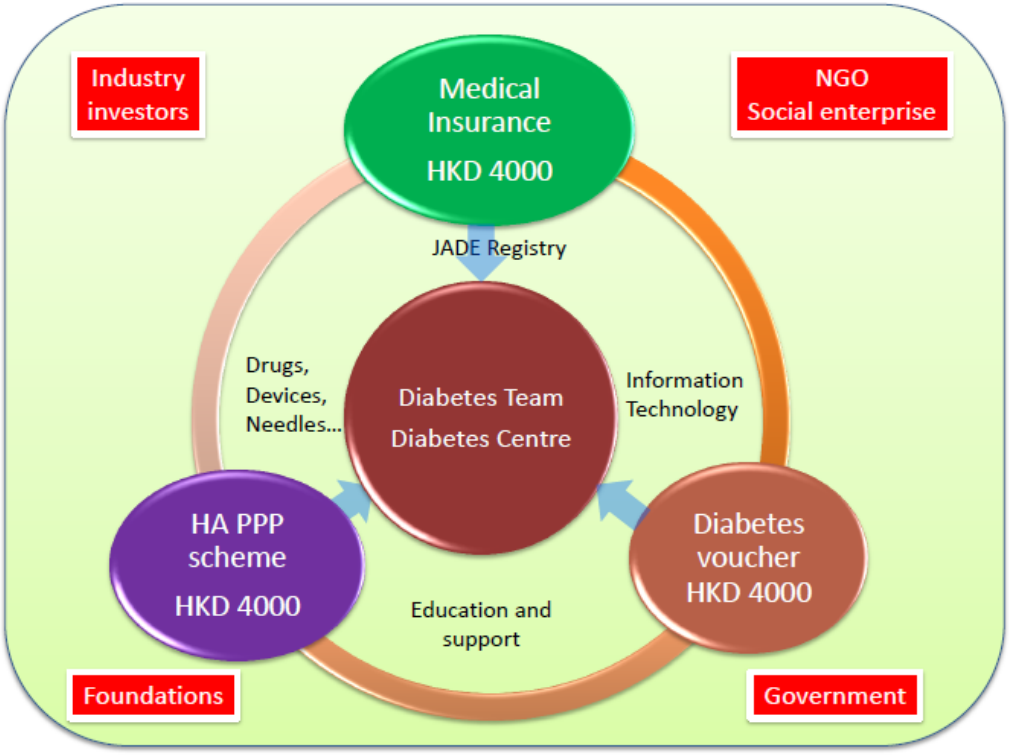


Figure 15 A possible funding model where insurers, HA and Bureau can jointly contribute towards an annual diabetes care plan of approximately HKD 10,000-12,000, depending on risk profiles and control of risk factors, to promote a stable doctor-patient relationship with linkage to a diabetes centre and a registry for quality assurance.

5.2. Moving forward for a win-win-solution for all

As part of a holistic strategy to prevent and control diabetes and non communicable disease (NCD), the public should be made aware on the what, why and how of health risk assessment and management. Depending on their risk profiles (e.g. age, sex, family history, social habits, body weight), they can be given incentive schemes such as health vouchers or pre-paid packages to undergo regular screening for common risk factors (e.g. blood pressure, blood glucose, blood lipids, body weight, urate level and renal function).

Upon detection of these risk factors, notably diabetes, they can be encouraged to join community-based diabetes centres, coordinated by paramedics, health care workers, patients or peers focusing on lifestyle modification, stress management and social support, supported by doctors with credentials in diabetes/chronic disease management, linked to a registry administered by an independent party for monitoring of care standards and default.

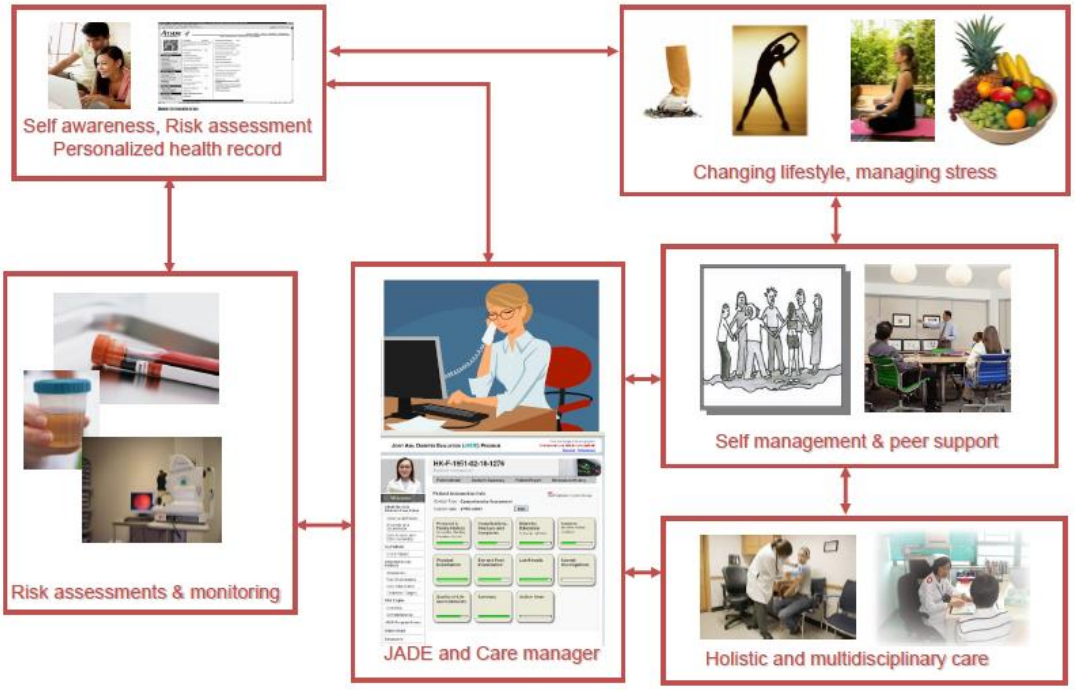


Figure 16 A schematic diagram showing an integrated care model comprising of self monitoring of common risk factors and in the case of diabetes, regular comprehensive assessment and empowerment provided by a multidisciplinary team linked to a Diabetes Centre and a Registry

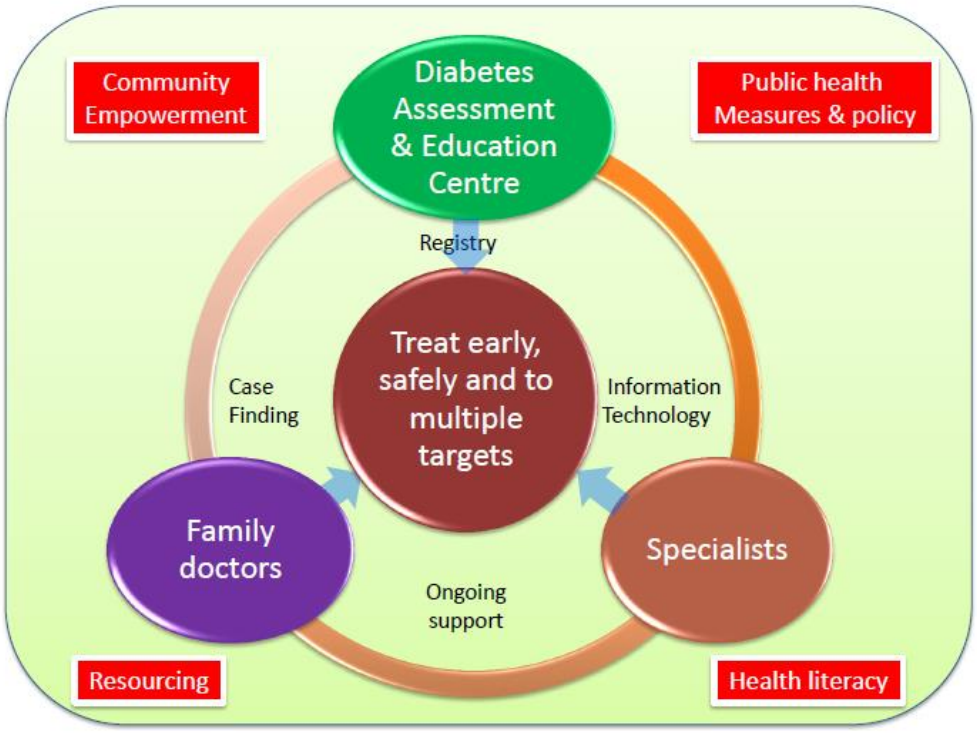


Figure 17 The multifunctional roles of a diabetes centre to promote awareness, organize outreach and support programs, detect undiagnosed disease, provide comprehensive assessment and education and establish a Diabetes Registry.

The establishment of these district-based diabetes centres can provide comprehensive assessment, education (self monitoring of blood glucose, insulin injection, pumps, ambulatory blood glucose or blood pressure monitoring), counselling, fun activities and ongoing support to complement medical care to make quality diabetes care accessible and user-friendly.

5.3. Conclusion

In pursuit of quality diabetes care, payors, notably insurers and government, play a pivotal role in promoting cost-effective preventive care and reducing incentives for expensive treatment with little added value. A successful PPP scheme for diabetes is dependent on a shared vision by all stakeholders, including but not limited to generalists, specialists, allied health workers, administrators, industry, to protect the health and interest of the person at risk or with diabetes, supported by mandates, audits and incentives [25].

During the last 2-3 decades, Hong Kong has been in the forefront of diabetes research, care and education [51]. Through innovation and partnerships to translate these decades of local evidence to quality care through PPP, Hong Kong is in a prime position to develop a flagship program in diabetes care and turn our city into a hub of health care excellence, while making our health care system more sustainable.

6. References

1. Quan J, Li TK, Pang H, et al. Diabetes incidence and prevalence in Hong Kong, China during 2006-2014. *Diabetic medicine* 2016.
2. Chan JCN, So WY, Ma RCW, Tong PCY, Wong R, Yang X. The complexity of vascular and non-vascular complications of diabetes: The Hong Kong Diabetes Registry. *Curr Cardiovasc Risk Rep* 2011; **5**: 230-9.
3. Chan JC, Malik V, Jia W, et al. Diabetes in Asia: epidemiology, risk factors, and pathophysiology. *JAMA* 2009; **301**(20): 2129-40.
4. Chan JC, Zhang Y, Ning G. Diabetes in China: a societal solution for a personal challenge. *The lancet Diabetes & endocrinology* 2014; **2** (12): 969-79.
5. Luk AO, Ma RC, Lau ES, et al. Risk association of HbA1c variability with chronic kidney disease and cardiovascular disease in type 2 diabetes: prospective analysis of the Hong Kong Diabetes Registry. *Diabetes/metabolism research and reviews* 2013; **29**(5): 384-90.
6. Luk AO, Lau ES, So WY, et al. Prospective study on the incidences of cardiovascular-renal complications in chinese patients with young-onset type 1 and type 2 diabetes. *Diabetes care* 2014; **37**(1): 149-57.
7. Chan JC, Lau ES, Luk AO, et al. Premature Mortality and Co-morbidities in Young-onset Diabetes - A 7 year Prospective Analysis. *The American journal of medicine* 2014; **127**(7): 616-24.
8. So WY, Tong PC, Ko GT, et al. Effects of protocol-driven care versus usual outpatient clinic care on survival rates in patients with type 2 diabetes. *The American journal of managed care* 2003; **9**(9): 606-15.
9. Chan JC, So WY, Yeung CY, et al. Effects of structured versus usual care on renal endpoint in type 2 diabetes: the SURE study: a randomized multicenter translational study. *Diabetes care* 2009; **32**(6): 977-82.
10. Leung WYS, So WY, Tong PCY, Chan NN, Chan JCN. Effects of structured care by a pharmacist-diabetes specialist team in patients with type 2 diabetic nephropathy. *American Journal of Medicine* 2005; **118**: 1414.e421-.e427.
11. Wu JY, Leung WY, Chang S, et al. Effectiveness of telephone counselling by a pharmacist in reducing mortality in patients receiving polypharmacy: randomised controlled trial. *Bmj* 2006; **333**(7567): 522.
12. Yeung RO, Yin J, Chan JCN. Integrated Diabetes Care in Hong Kong: From Research to Practice to Policy. In: Simmons D, Wenzel H, Zgibor JC, eds. Integrated Diabetes Care A Multidisciplinary Approach.

Switzerland Springer International Publishing; 2017: 65-85.
13. Chan JCN, Cockram CS. Organisation of diabetes care - Western Pacific Region (Hong Kong and China as examples). In: DeFronzo A, Feranninni E, Keen H, Zimmet P, eds. International Textbook of Diabetes Mellitus. Third ed: John, Wiley & Son; 2004.
14. Norris SL, Lau J, Smith SJ, Schmid CH, Engelgau MM. Self-management education for adults with type 2 diabetes: a meta-analysis of the effect on glycemic control. *Diabetes care* 2002; **25**(7): 1159-71.
15. Yeung RO, Zhang Y, Luk A, et al. Metabolic profiles and treatment gaps in young-onset type 2 diabetes in Asia (the JADE programme): a cross-sectional study of a prospective cohort. *The lancet Diabetes & endocrinology* 2014; **2**(12): 935-43.
16. Jiao F, Fung CS, Wan YF, et al. Long-term effects of the multidisciplinary risk assessment and management program for patients with diabetes mellitus (RAMP-DM): a population-based cohort study. *Cardiovascular diabetology* 2015; **14**: 105.
17. Wong CK, Wong WC, Wan YF, et al. Patient Empowerment Programme in primary care reduced all-cause mortality and cardiovascular diseases in patients with type 2 diabetes mellitus: a population-based propensity-matched cohort study. *Diabetes, obesity & metabolism* 2015; **17**(2): 128-35.
18. Hospital Authority Annual Report 2014-2015: Hong Kong Hospital Authority, 2015.
19. Szecsenyi J, Rosemann T, Joos S, Peters-Klimm F, Miksch A. German diabetes disease management programs are appropriate for restructuring care according to the chronic care model: an evaluation with the patient assessment of chronic illness care instrument. *Diabetes care* 2008; **31**(6): 1150-4.
20. Campbell D, Marsh S. NHS crisis: 20 hospitals declare black alert as patient safety no longer assured. 2017. https://www.theguardian.com/society/2017/jan/11/nhs-crisis-20-hospitals-declare-black-alert-as-patient-safety-no-longer-assured (accessed 12 January 2017.
21. Raz I, Riddle MC, Rosenstock J, et al. Personalized management of hyperglycemia in type 2 diabetes: reflections from a Diabetes Care Editors' Expert Forum. *Diabetes care* 2013; **36**(6): 1779-88.
22. Fisher EB, Chan JCN, Nan H, Sartorius N, Oldenburg B. Co-occurrence of

diabetes and depression: conceptual considerations for an emerging global health challenge. *Journal of affective disorders* 2012; **142 Suppl**: :S56-66.
23. Fisher EB, Brownson CA, O'Toole ML, Shetty G, Anwuri VV, Glasgow RE. Ecological approaches to self-management: the case of diabetes. *American journal of public health* 2005; **95**(9): 1523-35.
24. Chan JC, Sui Y, Oldenburg B, et al. Effects of Telephone-Based Peer Support in Patients With Type 2 Diabetes Mellitus Receiving Integrated Care: A Randomized Clinical Trial. *JAMA internal medicine* 2014; **174**(6:): 972-81.
25. Farrell D, Henke NP, Mango PD. Universal principles for health care reform *The McKinsey Quarterly* 2007: 87-97.
26. Ko GT, So WY, Tong PC, et al. From design to implementation--the Joint Asia Diabetes Evaluation (JADE) program: a descriptive report of an electronic web-based diabetes management program. *BMC medical informatics and decision making* 2010; **10**: 26.
27. Chan JC, Ozaki R, Luk A, et al. Delivery of integrated diabetes care using logistics and information technology - The Joint Asia Diabetes Evaluation (JADE) program. *Diabetes Res Clin Pract* 2014; **106 Suppl 2**: S295-304.
28. Yin J, Kong AP, Chan JC. Prevention and Care Programs Addressing the Growing Prevalence of Diabetes in China. *Current diabetes reports* 2016; **16**(12): 130.
29. Yin J, Wong R, Au S, et al. Effects of Providing Peer Support on Diabetes Management in People With Type 2 Diabetes. *Annals of family medicine* 2015; **13 Suppl 1**: S42-9.
30. Yin J, Yeung R, Luk A, et al. Gender, diabetes education, and psychosocial factors are associated with persistent poor glycemic control in patients with type 2 diabetes in the Joint Asia Diabetes Evaluation (JADE) program. *Journal of diabetes* 2016; **8**(1): 109-19.
31. So WY, Raboca J, Sobrepena L, et al. Comprehensive risk assessments of diabetic patients from seven Asian countries: The Joint Asia Diabetes Evaluation (JADE) program. *Journal of diabetes* 2011; **3**(2): 109-18.
32. Chan JC, Yeung R, Luk A. The Asian diabetes phenotypes: challenges and opportunities. *Diabetes Res Clin Pract* 2014; **105**(1): 135-9.
33. Kong AP, Yang X, Ko GT, et al. Effects of treatment targets on subsequent cardiovascular events in Chinese patients with type 2 diabetes. *Diabetes care* 2007; **30**(4): 953-9.

34. Miccoli R, Penno G, Del Prato S. Multidrug treatment of type 2 diabetes: a challenge for compliance. *Diabetes care* 2011; **34 Suppl 2**: S231-5.
35. Chan J, So W, Ko G, et al. The Joint Asia Diabetes Evaluation (JADE) Program: a web-based program to translate evidence to clinical practice in Type 2 diabetes. *Diabetic medicine : a journal of the British Diabetic Association* 2009; **26**(7): 693-9.
36. Del Prato S. Megatrials in type 2 diabetes. From excitement to frustration? *Diabetologia* 2009; **52**(7): 1219-26.
37. Holman RR, Paul SK, Bethel MA, Matthews DR, Neil HA. 10-year follow-up of intensive glucose control in type 2 diabetes. *The New England journal of medicine* 2008; **359**(15): 1577-89.
38. Stratton IM, Cull CA, Adler AI, Matthews DR, Neil HA, Holman RR. Additive effects of glycaemia and blood pressure exposure on risk of complications in type 2 diabetes: a prospective observational study (UKPDS 75). *Diabetologia* 2006; **49**(8): 1761-9.
39. Clarke PM, Gray AM, Briggs A, et al. A model to estimate the lifetime health outcomes of patients with type 2 diabetes: the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes Model (UKPDS no. 68). *Diabetologia* 2004; **47**(10): 1747-59.
40. Kroese DP, Brereton T, Taimre, Botev ZI. Why the Monte Carlo method is so important today. *WIREs Comp Stat* 2014; **6**: 386-92. doi: 10.1002/wics.314.
41. So WY, Chan JC. The role of the multidisciplinary team. In: Holt R, Cockram S, Flyvbjerg A, Goldstein B, eds. Textbook of Diabetes Blackwell; 2010: 969-83.
42. Lee VW, Chan WK, Lee KK. A cost analysis in patients with acute coronary syndrome using clopidogrel in addition to aspirin in a Hong Kong public hospital. *International heart journal* 2006; **47**(5): 739-44.
43. Ioannides-Demos LL, Makarounas-Kirchmann K, Ashton E, Stoelwinder J, McNeil JJ. Cost of myocardial infarction to the Australian community: a prospective, multicentre survey. *Clinical drug investigation* 2010; **30**(8): 533-43.
44. Yu R, Chau PH, McGhee SM, et al. Trends of Disease Burden Consequent to Stroke in Older Persons in Hong Kong: Implications of Population Ageing. . Hong Kong The Hong Kong Jockey Club, 2012.
45. Yu AW, Chau KF, Ho YW, Li PK. Development of the "peritoneal dialysis first" model in Hong Kong. *Peritoneal dialysis international* 2007; **27**

Suppl 2: S53-5.
46. Yang F, Khin LW, Lau T, et al. Hemodialysis versus Peritoneal Dialysis: A Comparison of Survival Outcomes in South-East Asian Patients with End-Stage Renal Disease. *PLoS One* 2015; **10**(10): e0140195.
47. Segal L, Leach MJ, May E, Turnbull C. Regional primary care team to deliver best-practice diabetes care: a needs-driven health workforce model reflecting a biopsychosocial construct of health. *Diabetes care* 2013; **36**(7): 1898-907.
48. Tricco AC, Ivers NM, Grimshaw JM, et al. Effectiveness of quality improvement strategies on the management of diabetes: a systematic review and meta-analysis. *Lancet* 2012; **379**(9833): 2252-61.
49. Zhang P, Engelgau MM, Norris SL, Gregg EW, Narayan KM. Application of economic analysis to diabetes and diabetes care. *Annals of internal medicine* 2004; **140**(11): 972-7.
50. Johnson FR, Manjunath R, Mansfield CA, Clayton LJ, Hoerger TJ, Zhang P. High-risk individuals' willingness to pay for diabetes risk-reduction programs. *Diabetes care* 2006; **29**(6): 1351-6.
51. Zhao X, Guo L, Yuan M, et al. Growing Trend of China's Contribution to Global Diabetes Research: A Systematic Literature Review. *Medicine* 2016; **95**(18): e3517.