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Impact of Epidemic Rates of Diabetes on the Chinese Blood Glucose Testing Market

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Abstract

China has become the country with the largest diabetes mellitus population in the world since the 1990s. About 100 million diabetes cases have been diagnosed since 2008. Handheld blood glucose meters and test strips are urgently needed for daily patient measurement. The glucose monitor with a screen-printed carbon-based glucose electrode has been in commercial production since 1994. Since then, approximately 20 companies have been involved in manufacturing and marketing meters and test strips in China. The current market and production volume and updates on technology issues are discussed in this article.

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Introduction

Glucose sensors account for approximately 95% of the current Chinese market for biosensors, which have been estimated at approximately $80–100 million.[1,2] The reasons why the blood glucose market was particularly receptive are numerous, but the biggest factor is the prevalence of diabetes in China. In a countrywide study[3] from June 2007 through May 2008 in 14 provinces and municipalities, 92.4 million adults with diabetes were confirmed (50.2 million men and 42.2 million women) and a further 148.2 million adults were also found with prediabetes (76.1 million men and 72.1 million women). These results indicate that diabetes has become a major public health problem in China, and national strategies aimed at preventing, detecting, and treating diabetes are urgently needed. The report also reveals that diabetes in rural residents has been rated at 8.2%, i.e., approximately 43.1 million persons suffered, which is a very high volume compared with only 0.65% 10 years earlier. The situation is even worse still; incidence of the disease has risen 10–12% annually since 2005, and a further 15% annual increase in new cases is predicted from 2015–2020 (**Table 1**).

Table 1.
Fast Growing Patients of Type 2 Diabetes[2]

Statistics (year)	1980	1996	2002	2010	2015
The percentage of total populations (%)	0.67	3.21	5	7	10
The national average income (U.S. dollar)[4]	100	424	988	4361	~6000

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Abbreviations: (CV) coefficient of variation

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Because education regarding the disease is in some cases weak, the use of self-monitoring of blood glucose systems is not very popular among most patients with diabetes, who feel it is inconvenient and costs a lot. But the inherent thinking is changing. Because patients with diabetes have to control their blood glucose levels carefully, self-monitoring of blood glucose has been widely recognized as an important and effective method of measuring blood sugar not only in clinics, but also at home and in the workplace.[5] Therefore, the domestic blood glucose testing market will be activated greatly. A variety of blood glucose meters have been developed with advanced technology toward high sensitivity, selectivity, reliability, and low cost.

Development of Glucose Biosensor Technology in China

In the early 1990s, the authors tried to use screen-printing technology for local mass production of glucose sensors. The first glucose meter (SENTEST) and test strip in China was created in the end of 1993 and successfully commercialized 1 year later by Beijing Yicheng Bioelectronics Company.[6] This was the first commercial blood glucose meter using carbon-paste screen-printing technology, for which enzyme electrodes (test strips) were mass produced and were extremely inexpensive, highly reproducible, reliable, and single use (disposable; **Figure 1A**). Two years later, a similar glucose meter, GluTest, was launched in Wuhan (**Figure 1B**). The meter has a function of automatic temperature compensation, aiming to overcome the effect of environmental temperature change on blood glucose measurement.[7]

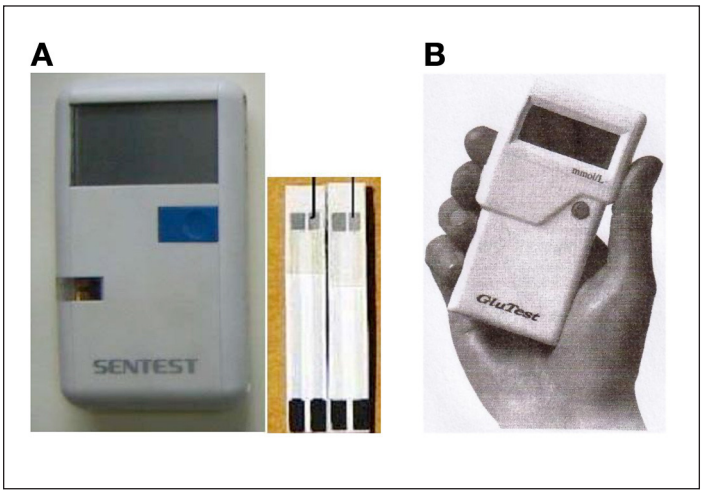

Figure 1. First generation of glucose testing systems in China: **(A)** SENTEST from Beijing Yicheng Bioelectronics and **(B)** GluTest from Keyuan, Wuhan

These early events have given a strong push to the blood glucose market in China. So far, approximately 20 manufacturers and 30,000 people are involved in this business countrywide. Until now, all subsequent products produced by different local companies have utilized very similar technology. The basic concept involves an amperometric biosensor employing glucose oxidase and a ferricyanide electrochemical mediator on a disposable strip format. Although various improvements have been developed, the concept has remained largely unaffected.

Table 2 is a list of defining points in the development of commercialized glucose testing systems.

Beijing Yicheng Bioelectronics

Founded in 1993, Beijing Yicheng Bioelectronics is the company that launched the first screen-printed enzyme electrode and blood glucose testing system in China. It employs over 200 people and, in 2009, produced 300,000 glucose meters of different types plus 100 million electrochemical glucose test strips. Revenues in 2009 were approximately $15 million. In early 2010, the company announced that they received a $1.08 million venture capital investment in cash from Sequoia Capital China; for company research and development and a production line extension. The top-selling glucose meter system is JPS-5 (**Figure 2**). The meter test time is 25 s with a 3 μl blood sample. The system provides voice prompts to help those who have reduced vision.

MicroSense, Inc.

Shanghai MicroSense's primary biosensor products are rapid blood glucose monitoring systems, an area it first became involved in when it introduced the technology from Shanghai Research Institute of Industrial Microbiology

Table 2.
Some Main Developments in the History of Commercialized Glucose Testing Systems in China

Date	Event
1993	First glucose testing system was launched by Beijing Yicheng Bioelectronics
1996	Acon established a production line of reflective glucose meters and test strips in Hangzhou
2000	Shanghai MicroSense launched a commercialized electrochemical glucose sensor
2002	Sinocare established in Changcha, Hunan, and launched its first glucose sensor
2006	Acon announced an electrochemical glucose sensor launched in this year

in 1990. But the first successfully commercialized glucose meter was in 2000. The company markets two kinds of glucose monitoring systems, named Jinqu, meaning golden magpie (**Figure 3**).

The Jinqu XS-1 features a 20 s testing time from a 20 μl blood sample and a top-loading format and records 30 test memories (test range 40–500 mg/dl).

The Jinqu XS-3 is similar in principle but has improved test strips with sample capillary fill; sample volume is dropped to 3 μl. Limitations of these devices include a poor coefficient of variation (CV), which is ≤7.5%, and across 35–55% hematocrit, the blood glucose test range is narrower than most popular machines.

Acon Laboratories, Inc.

Acon Laboratory was established in San Diego, CA, and then moved their production facilities to Hangzhou, China, in 1995. As of 20 June 2011, Acon is the largest glucose testing system manufacturer in China. The company has approximately 300 employees and produces 150 million electrochemical glucose test strips and 250,000 test meters and also produces 5 million optical vision strips annually. Ninety percent of total products are exported to Southeast Asia, Africa, South America, and Middle Eastern countries. Domestic revenues were estimated at $25 million. They announced that the second electrochemical glucose test strips production line was finished in early 2010, and by the middle of 2011, the volume of electrochemical test strips will double to approximately 300 million strips. According to the huge demand for glucose testing products, the company is trying to change their sales policy and focus more on the domestic market.

Figure 2. Beijing Yicheng Bioelectronics Super JPS-5 glucose monitor.

Acon Laboratory markets a range of instruments and accessories for both home and hospital use. The electrochemical glucose monitor On-Call system was launched in 2006 (**Figure 4A**), which features two-button operations. Insertion of the test strip automatically turns the meter on. A 1 μl sample is drawn into the test strip by capillary fill, providing an answer within 9 s. A 300-test memory is built in and shows 7-, 14-, and 30-day averages. The precision CV ≤ 5.5% and across 35–55% hematocrit.

The latest instrument is the On-Call Advanced (**Figure 4B**), which is available for capillary, venous, and neonatal blood testing. The pyrroloquinoline-quinone-dependent glucose dehydrogenase is used as an alternative enzyme for glucose testing. The meter requires only 0.8 μl of blood and displays results in 5 s. A 300-test memory is

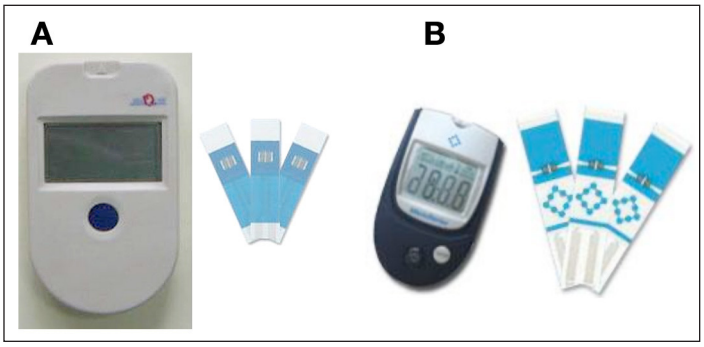

Figure 3. Blood glucose **(A)** Jinqu XS-1 and **(B)** Jinqu XS-3 and their test strips, made by MicroSense, Inc., Shanghai.

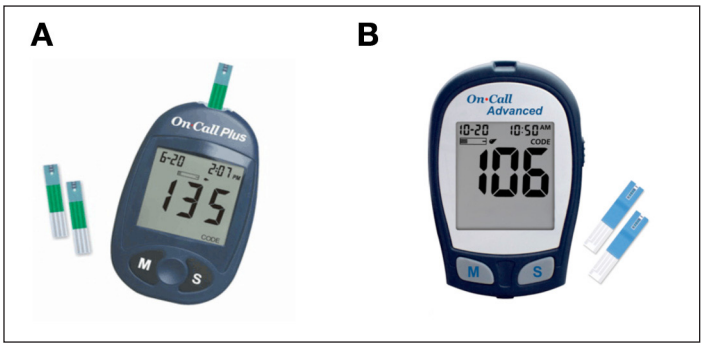

Figure 4. Acon **(A)** On-Call glucose monitor system and **(B)** its advanced type. Reproduced from Acon's official Web site.

also built in. The glucose test range is 10–600 mg/dl and across 20–70% hematocrit.

Acon also has a substantial dry reagent and urinalysis business based on fairly standard test strip technology. These can feature numerous tests on a single strip, which could adopt a reflectance approach. In addition, the company is developing Bio-Chem and immune chips for a number of analytes, including glucose, cholesterol, and uric acid.

Sinocare, Inc.

The main biosensors products sold by Sinocare are the Sannuo blood glucose systems. The company launched its first type of glucose monitor in 2002.

Sannuo SXT-2 (**Figure 5A**) is the top-selling meter of the company, and it uses carbon-paste printing for conducting track and reference/working electrodes. The test strip is designed for side-fill capillary action, requiring a 3 μl blood sample, with data readout in 25 s. It features an automatic on/off function with a 220-value memory storage (with times and dates and 7-, 14-, and 28-day averages). The glucose test range is 40–500 mg/dl with CV ≤ 7.5%.

Sannuo SXT-3 (**Figure 5B**) has now been launched, and it uses similar technology, but blood sample volume is dropped down to 0.6 μl.

Tianjin Andon Health Co., Ltd.

The company was found in 1995 in Tianjin and went public in 2007. It is the third player in the world of blood pressure meter production. Based on its strong net sales in blood pressure meters, it entered into the blood glucose market. It has only one type of glucose test system (**Figure 6**) but plans to take 25–30% of the local blood glucose testing products market by 2014.

Fabrication and Screen-Printing Technology

The ability to produce test strips in large amounts and at a low cost is a major requirement for glucose biosensors, particularly those aimed at self-care testing markets, where one-shot use has many advantages.[8] As discussed previously, screen printing has had a huge impact on the commercialization of blood glucose sensors. Almost all local manufacturers are using this technique. A typical production screen printer is shown in **Figure 7**.

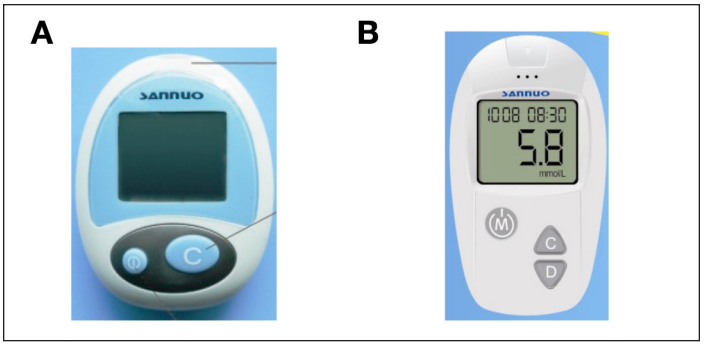

Figure 5. Sannuo glucose monitors (A) SXT-2 and **(B)** SXT-3. Reproduced from Sinocare's official Web site.

Figure 6. Andon blood glucose test meter. Reproduced from the company's Website.

Inks used in the production of test strips are strict. Low-firing-temperature (75–100 °C) carbon-based inks are normally selected to prepare the base electrode. For cost reasons, the dual-carbon electrode (working and reference) format is widely adopted, and silver/silver chloride ink is rarely used. This leads to mass production of blood glucose test strips at a very low cost.

Improved Systems and Future Developments

Although the blood glucose meters are mature, interference with the reaction between glucose oxidase and glucose remains a major concern. One of the solutions is to seek

connection of the redox center of the enzyme protein to the electrode via a molecular wire. This could be approached by modifying the enzyme and/or mediators.[9] Beijing Yicheng Bioelectronics is now trying to use osmium compound to "wire" the enzyme. An enzyme electrode was fabricated by mixing the modified enzyme with carbon inks or some other reagents, creating enzyme inks. The initial results showed that the glucose linearity can be up to 50 mM, and the system effectively eliminated most common interferences. However, the basic design of the commercially successful glucose monitors has not changed significantly since the beginning. Almost all mediated amperometric designs are similar to the original format of the MediSense device launched in the 1990s. The local companies have been slow and careful to introduce new technology and/or have relied on a strategy of putting existing technology in a new box. **Table 3** shows the technique characteristics of the major commercially available glucose testing systems made in China.

Market Analysis and Perspective

The set list of production volume for local manufacturers is little changed. In 2009, the biggest productivity came from Acon in Hangzhou, which produced 150 million test strips. Beijing Yicheng Bioelectronics has dropped to second place, with 100 million test strips. Sinocare produced 70–80 million test strips, and then Shanghai MicroSense produced 8–10 million. **Figure 8A** shows the distribution of total productivity. But investigating the sales market, the figure is very different (**Figure 8B**); the top three will be Beijing Yicheng first, Sinocare second, and Acon in third place, because Acon is focused mainly on the international market.

According to one report, there are 100 million diabetes cases in China.[3] Considering that more and younger patients with diabetes are being added to the group, the requirements for glucose meters and test strips will be enormous in coming years. A recent survey[10] reveals that 12–15 million glucose meters with 2–3 billion test strips will be needed every year through 2016. As the products are not listed in a proposal of medical insurance guided by the government so far, most of these products will flow to the local over-the-counter market. In this case, price would be the key concern for people with diabetes. A market investigation carried out in 2007[10] noted that one strip for one yuan ($0.15) would be acceptable to the majority of local patients with diabetes, and now the era is coming. The wholesale price of most local brands

Figure 7. A production scale of a screen printer. Reproduced from Shanghai Bioscan Inc.

Table 3.
Technique Characteristics of Local Brand Glucose Biosensors

	Yicheng	Sannuo	Acon	MicroSense	Andon
Sample size (μl)	1	3	0.8	3	1
Test time (seconds)	5	10	5	20	5
Capillary fill strip	Yes	Yes	Yes	Yes	Yes
Test memory	245	220	300	300	250
Alternate site testing	No	No	Yes	No	No
Data downloading	Yes	No	Yes	No	No
No coding	No	No	No	No	No
Plasma calibration	No	No	Yes	No	No
Glucose oxidase	Yes	Yes	Yes	Yes	Yes
Glucose dehydrogenase	No	No	Yes	No	No

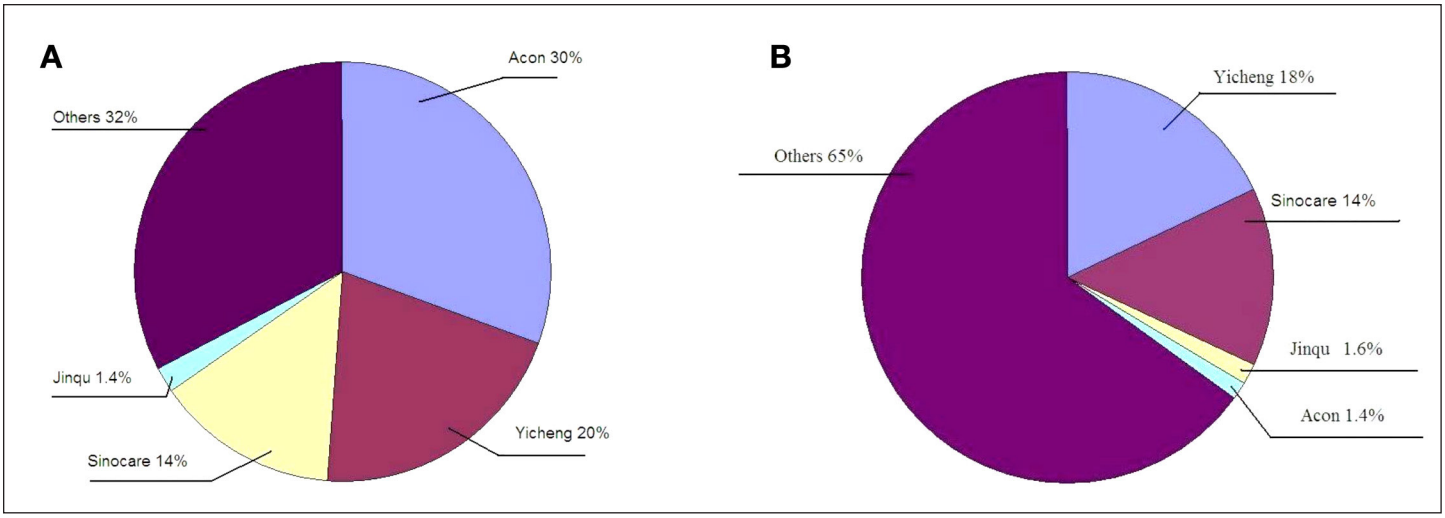

Figure 8. (A) Distribution of the total productivity and **(B)** the market shares of the local players in China in 2009.

is currently down to 0.6–0.8 yuan/strip (approximately $0.10), selling at retail for approximately 1.2–1.6 yuan/strip (approximately $0.20). People can find inexpensive test strips from Internet shops at 1.6–2 Yuan/strip ($ 0.30) with Lifescan and Roche Accuchek-Active brands.

Conclusions

Diabetes is becoming an epidemic disease in China, and diabetes-detecting products are very much needed. It is estimated that, when 50% of Chinese patients with diabetes are using a glucose monitor daily, a huge market will emerge (in 2014–2016) and count for approximately USD 1 billion per year.

In the absence of a cure for diabetes, home blood glucose monitoring will need to continue, and the current commercial dominance of mediated electrochemical biosensors will not be easily replaced. Although local manufacturers are relatively young compared to their Western partners, significant improvements in their products are expected to be achieved by incorporating new technologies, such as new printed materials and advanced printing technology, and these technology developments will lead to the enhancement of reproducibility and sensitivity of screen-printed carbon-based strips. With this aim, new efforts to modify the working and counter electrodes are ongoing, with the focus on new enzymes, new mediators, conducting polymers, and nanostructure materials.

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Disclosure:

Jamie Hu is a full-time employee of Shanghai Bioscan, Inc.

References:

1. Hu J. The evolution of commercialized glucose sensors in China. Biosens Bioelectron. 2009;24(5):1083–9.
2. K Xiang, W Yang; China guideline for diabetes. 2009. (in Chinese)
3. Yang W, Lu J, Weng J, Jia W, Ji L, Xiao J, Shan Z, Liu J, Tian H, Ji Q, Zhu D, Ge J, Lin L, Chen L, Guo X, Zhao Z, Li Q, Zhou Z, Shan G, He J; China National Diabetes and Metabolic Disorders Study Group. Prevalence of diabetes among men and women in China. N Engl J Med. 2010;362(12):1090–01.
4. Economy of People's Republic of China. 2010. http//en.wikipedia.org/wiki/Economy_of_the_People's_Republic_of_China.
5. Martin S, Schneider B, Heinemann L, Lodwig V, Kurth HJ, Kolb H, Scherbaum WA. Self-monitoring of blood glucose in type 2 diabetes and long-term outcome: an epidemiological cohort study. Diabetologia. 2006;49(2):271–8.
6. Hu J. SenTestTM from single carbon enzyme electrode to mass production of biostrips. Adv Biosens. JAI Press INC. 1999;(4):315–25.
7. Zhang XE. Recent developments of biosensors. Adv Biosens. JAI Press INC. 1999;(4):179–93.
8. Zhang XE. Screen-printing methods for biosensor production. In: Cooper JM, Cass AE. Biosensors: a practical approach, 2nd ed. New York: Oxford University Press; 2004, 41–58.
9. Chen LQ, Zhang XE, Xie WH, Zhou YF, Zhang ZP, Cass AE. Genetic modification of glucose oxidase for improving performance of an amperometric glucose biosensor. Biosens Bioelectron. 2002;17(10):851–7.
10. HMI. China blood glucose monitor market research report in 2007 http://www.allmyinfo.com/eng/Report/index3_5.asp.