

## · 论著 ·

## 2005—2014 年 CHINET 大肠埃希菌耐药性监测

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**摘要:** **目的** 了解中国 2005—2014 年, CHINET 所属 19 所医院临床分离大肠埃希菌的耐药情况。**方法** 按照统一方案, 采用统一材料、方法和判断标准, 进行临床分离大肠埃希菌耐药性监测, 并用 WHONET5.6 软件进行数据分析。**结果** 2005—2014 年共收集 19 所医院临床分离的大肠埃希菌 97 493 株, 其中 75.5% 来自住院患者; 49.8% 菌株分离自尿液标本。10 年间, 大肠埃希菌的检出率呈稳步上升趋势: 2005 年为 17.3%, 2014 年为 20.9%。药敏试验结果显示, 不同医院分离出的大肠埃希菌对不同种类抗菌药物的耐药性各具特点。10 年间, 细菌对各种抗菌药物的耐药性发生一定变化, 对部分第二代、第三代头孢菌素耐药率呈稳定上升趋势, 如对头孢呋辛的耐药率由 52.8% 上升到 62.8%、对头孢他啶由 14.9% 上升到 28.8% 等; 但对氨基糖苷类抗生素耐药性有缓慢下降趋势, 如对阿米卡星由 12.0% 降至 4.0%、对庆大霉素由 60.4% 降至 46.6%、对妥布霉素由 30.3% 降至 19.0%; 对碳青霉烯类抗生素的耐药率稳定在 0.2%~2.2%; 对酶抑制剂复方制剂除氨苄西林-舒巴坦的耐药率已超过 50% 外, 对其余品种的耐药率均 <20%。ICU 分离菌的耐药率明显高于其他科室的分离菌, 门诊和住院患者分离菌的耐药率也有明显差别 ( $P<0.05$ )。不同标本来源的大肠埃希菌对不同种类抗菌药物的耐药率有一定的差异, 呼吸道标本分离菌对青霉素、头孢菌素类的耐药率明显高于其他标本的分离株。从不同患者分离出的菌株, 对抗菌药物的耐药率存在老年人 > 成人 > 儿童 > 新生儿。不同年份, 不同医院产 ESBL 大肠埃希菌的检出率也不尽相同, 10 年间所有菌株 ESBL 的总检出

率为 42.3%, 观察期间产 ESBL 大肠埃希菌的检出率总体呈上升趋势, 2014 年检出率最高, 达 55.5%。产 ESBL 大肠埃希菌对检测的各种抗菌药物的耐药率远高于非产 ESBL 菌株 ( $P<0.05$ )。

**结论** 不同医院、不同科室、不同标本中分离的大肠埃希菌对常用抗菌药物的耐药性有着不同的特点。各医院应继续加强细菌耐药监测工作, 以指导抗生素的合理选用。

**关键词:** 大肠埃希菌; 耐药性监测; 抗菌药物

**中图分类号:** R378.21 **文献标识码:** A **文章编号:** 1009-7708(2016)02-0129-12

**DOI:** 10.16718/j.1009-7708.2016.02.004

**基金项目:** 国家自然科学基金 (81171618)。

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## Susceptibility of *Escherichia coli* strains in hospitals across China: results from the CHINET Antimicrobial Resistance Surveillance Program, 2005-2014

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**Abstract:** **Objective** To investigate the antimicrobial resistance of *E. coli* strains isolated from 19 hospitals across China in the CHINET Antimicrobial Resistance Surveillance Program during the period from 2005 through 2014. **Methods** Antimicrobial susceptibility testing was carried out according to a unified protocol using Kirby-Bauer or MIC method. Results were analyzed according to the breakpoints of CLSI 2014. WHONET 5.6 was used for data analysis. **Results** A total of 97 493 clinical strains of *E. coli* were collected from 2005 through 2014, 75.5% of which were isolated from inpatients, and 49.8% were from urine. The prevalence of *E. coli* increased with time from 17.3% in 2005 to 20.9% in 2014. Susceptibility testing showed that the resistance profile of *E. coli* strains varied with hospital. During the 10-year period, *E. coli* strains showed increasing resistance rate to second and third-generation cephalosporins, e.g., cefuroxime (52.8%→62.8%), and ceftazidime (14.9%→28.8%), but decreasing resistance rate to aminoglycosides, such as amikacin (12.0%→4.0%), gentamicin (60.4%→46.6%), and tobramycin (30.3%→19.0%). The percentage of *E. coli* strains resistant to carbapenems was steady, ranging from 0.2% to 2.2%. The resistance rate was relatively lower (<20%) to  $\beta$ -lactam/ $\beta$ -lactamase inhibitor combinations (excluding ampicillin-sulbactam). The *E. coli* strains isolated from ICU showed significantly higher resistance rates than those from other departments. The *E. coli* isolated from inpatients showed significantly different resistance rate from the strains from outpatients ( $P<0.05$ ). The strains isolated from respiratory specimens had higher resistance rate to penicillins and cephalosporins than the strains from other specimens. The resistance profile of the *E. coli* strains also increased with the age of patients (the strains from old patients>adults>children>newborns in terms of resistance rate). The prevalence of ESBLs-producing strains is variable among different hospitals and in different specific years. The overall prevalence of ESBLs-producing strain in *E. coli* isolates was 42.3%. The prevalence of ESBLs-producing strains was generally increasing from 2005 through 2014. The ESBLs-producing strains had significantly higher resistance than non-ESBLs-producing strains ( $P<0.05$ ). **Conclusions** The resistance profile of *E. coli* strains varies with hospitals, departments, and specimens where they are isolated. Therefore, it is necessary to conduct the surveillance program in hospitals for rational use of antibiotics.

**Key words:** *Escherichia coli*; antibiotic resistance; antimicrobial agent

大肠埃希菌是医院获得性感染的重要病原菌, 主要引起泌尿系统、呼吸道、腹腔、皮肤软组织及血流感染<sup>[1]</sup>。近年来, 该类细菌引起的感染问题日益严重, 表现为耐药率大幅上升, 多重耐药菌株数量急剧增加, 耐药谱逐渐增宽。对大肠埃希菌的耐药性监测是 CHINET 细菌耐药性监测项目中的重要组成部分。现将 2005—2014 年 CHINET 耐药性监测网有关大肠埃希菌的耐药性监测结果报道如下。

## 1 材料与方法

### 1.1 材料

**1.1.1 菌株来源与分离鉴定** 收集 2005 年 1 月 1 日—2014 年 12 月 31 日从我国不同地区 19 所医院临床分离的大肠埃希菌 97 493 株, 剔除同一患者相同部位重复分离的菌株, 各医院临床微生物实验室按常规操作规程将菌株鉴定到种, 按统一方

案进行细菌药敏试验。

**1.1.2 培养基与抗菌药物纸片** 药敏试验用的培养基 MH 琼脂 (Mueller Hinton agar) 及药敏试验纸片均为英国 OXOID 公司产品, 全自动药敏试验卡片为 VITEK-2 检测系统配套产品 (法国生物梅里埃公司)。

### 1.2 方法

**1.2.1 药敏试验** 采用 CLSI 推荐的纸片扩散法 (Kirby-Bauer) 进行<sup>[2]</sup>, 部分医院采用自动化仪器。质控菌株为大肠埃希菌 ATCC25922。

**1.2.2 ESBL 检测** 采用 CLSI 推荐的 ESBL 纸片筛选法和酶抑制剂增强试验确证法测定大肠埃希菌中产 ESBL 株。

**1.2.3 判断标准及统计分析** 药敏试验结果按 CLSI 2014 年标准判断<sup>[2]</sup>, 并用 WHONET 5.6 软件进行数据分析。采用 SPSS 软件进行  $\chi^2$  检验分析, 以  $P<0.05$  为差异有统计学意义。

2 结果

2.1 菌株来源及分布

全国不同地区 19 所医院 2005—2014 年共收集非重复大肠埃希菌 97 493 株。10 年间, 大肠埃希菌的检出率呈稳定上升趋势: 2005 年检出率为 17.3% (3 949/22 774), 2013 年和 2014 年已分别高达 19.9% (16 794/84 572) 和 20.9% (16 511/78 955)。见表 1。来自门急诊患者和住院患者的分离菌株分别占 24.5% (23 893 株) 和 75.5% (73 600 株)。所分离菌株最多来源于尿液 (49.8%), 其次是呼吸道 (15.8%) 和血液 (9.9%)。不同科室所分离大肠埃希菌, 主要来自于大内科 (29.5%) 和大外科 (26.1%), 其次是 ICU (5.4%) 和儿科 (4.6%)。

表 1 大肠埃希菌在所有临床分离株中的检出率  
Table 1 Prevalence of *E.coli* among all clinical isolates

| Year | Number | Total  | %    |
|------|--------|--------|------|
| 2005 | 3 949  | 22 774 | 17.3 |
| 2006 | 5 553  | 33 945 | 16.4 |
| 2007 | 6 524  | 36 001 | 18.1 |
| 2008 | 6 678  | 36 216 | 18.4 |
| 2009 | 7 992  | 43 670 | 18.3 |
| 2010 | 9 225  | 47 850 | 19.3 |
| 2011 | 10 861 | 59 287 | 18.3 |
| 2012 | 13 406 | 72 397 | 18.5 |
| 2013 | 16 794 | 84 572 | 19.9 |
| 2014 | 16 511 | 78 955 | 20.9 |

2.2 产 ESBL 和碳青霉烯酶耐药大肠埃希菌分布

产 ESBL 大肠埃希菌共 41 208 株, 门诊患者所占比例最大 (5 585 株, 13.6%), 其次是泌尿外科 (3 915 株, 9.5%)、ICU (2 788 株, 6.8%)、普外科 (2 483 株, 6.0%) 和肾内科 (1 823 株, 4.4%)。产碳青霉烯酶大肠埃希菌共 3 900 株, 占大肠埃希菌总数的 4.0%, 其中大内科所占比例最大 (1 284 株, 32.9%), 其次是大外科 (1 009 株, 25.9%)、门诊 (526 株, 13.5%) 和 ICU (361 株, 9.3%)。

2.3 产 ESBL 大肠埃希菌检出率

19 所医院 10 年产 ESBL 大肠埃希菌总检出率为 42.3%, 且 10 年间, 产 ESBL 大肠埃希菌的检出率总体呈上升趋势 (2010 年略下降, 为

39.5%), 2014 年检出率最高, 达 55.5%。不同科室中 ICU (53.5%) 和大外科 (50.4%) 产 ESBL 大肠埃希菌的检出率最高, 其次是新生儿科 (45.8%) 和儿科 (44.6%), 门急诊和住院患者 ESBL 检出率分别为 29.8% 和 46.3%。

2.4 药敏试验结果

2.4.1 19 所医院 10 年大肠埃希菌的药敏试验结果 97 493 株大肠埃希菌总的药敏试验结果显示对氨苄西林和哌拉西林的耐药率最高, 分别为 87.3% 和 75.3%; 其次是四环素和头孢唑林, 分别为 73.6% 和 70.9%。耐药率低于 10% 的抗菌药物有: 头孢哌酮-舒巴坦 (6.1%)、哌拉西林-他唑巴坦 (4.6%)、头孢美唑 (6.7%)、头孢替坦 (2.8%)、厄他培南 (1.5%)、亚胺培南 (1.1%)、美罗培南 (1.3%)、帕尼培南 (0.3%)、阿米卡星 (6.1%)、呋喃妥因 (6.3%)、替加环素 (0.6%); 其余抗菌药物的耐药率见表 2。

不同抗菌药物 10 年耐药率变化趋势有所不同, 头孢呋辛、头孢噻肟、头孢曲松、头孢他啶的耐药率呈稳定上升趋势, 而阿莫西林-克拉维酸、阿米卡星、庆大霉素、妥布霉素、呋喃妥因、甲氧苄啶-磺胺甲噁唑的耐药率却有缓慢下降的趋势。青霉素类、大部分酶抑制剂复方制剂、氟喹诺酮类、碳青霉烯类等抗菌药物 10 年的耐药率变化幅度小。头孢克洛的耐药率由 2005 年的 47.5% 上升至 2011 年的 61.5%, 但 2013 年和 2014 年仅为 24.7% 和 34.7%, 见表 3。

2.4.2 不同科室来源分离菌株对常见抗菌药物的耐药性 ICU 分离出的大肠埃希菌除替加环素外对其他 34 种抗菌药物的耐药率相比其他科室都是最高的。门诊患者分离出的大肠埃希菌对各种抗菌药物的耐药率均低于其他科室; 急诊分离株对碳青霉烯类抗生素的耐药率高于非 ICU, 对其他抗菌药物的耐药率基本相似, 见表 4。

2.4.3 不同标本来源临床分离株对常见抗菌药物的耐药性 总体而言, 呼吸道标本分离菌的耐药率最高, 对多种抗菌药物都有较高的耐药率。呼吸道标本的分离株对青霉素类、头孢菌素类、碳青霉烯类抗生素的耐药率明显高于其他标本; 排泄物标本来源的菌株对酶抑制剂复方制剂、氨基糖苷类和氟喹诺酮类抗菌药物的耐药率较高; 脑脊液标本对第三、第四代头孢菌素类, 单环  $\beta$  内酰胺类抗生素的耐药率偏高, 见表 5。

2.4.4 不同年龄患者分离株对常见抗菌药物的耐

表 2 不同医院 10 年分离的大肠埃希菌对常见抗菌药物的平均耐药率和敏感率  
Table 2 Susceptibility of *E. coli* to antimicrobial agents in different hospitals during 10 years

(%)

| Antibiotic                    | AYD  |      | BJH  |      | CQH  |      | GSY  |      | GZH  |      | HSH  |      | KMH  |      | PED  |      | PUH  |      | RJH  |      |
|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                               | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    |
| Ampicillin                    | 88.2 | 10.2 | 87.1 | 11.0 | 88.7 | 10.5 | 90.3 | 8.6  | 85.8 | 12.7 | 90.5 | 7.4  | 90.2 | 7.8  | 83.7 | 13.6 | 85.7 | 12.7 | 83.8 | 14.7 |
| Piperacillin                  | 79.5 | 14.4 | 77.3 | 16.2 | 74.2 | 22.1 | 79.8 | 14.3 | 73.2 | 18.5 | 84.6 | 12.3 | 72.7 | 18.0 | 68.2 | 23.6 | 68.1 | 23.4 | 70.1 | 21.0 |
| Amoxicillin-clavulanic acid   | 11.9 | 58.5 | NA   | NA   | NA   | NA   | 11.3 | 58.7 | 11.5 | 58.4 | 65.0 | 35.0 | 23.2 | 48.4 | 10.0 | 67.5 | 11.4 | 63.5 | NA   | NA   |
| Cefoperazone-sulbactam        | 10.7 | 70.9 | 11.6 | 66.4 | 10.7 | 76.1 | 4.7  | 79.0 | 10.1 | 67.5 | 8.6  | 67.5 | 4.3  | 78.9 | 3.4  | 81.1 | 4.3  | 82.9 | 3.6  | 84.7 |
| Ampicillin-sulbactam          | 57.1 | 23.9 | 48.8 | 31.5 | 57.1 | 28.8 | 46.4 | 30.5 | 49.0 | 32.1 | 60.1 | 20.5 | 56.4 | 21.6 | 32.9 | 40.8 | 31.7 | 48.7 | 38.7 | 43.0 |
| Ticarcillin-clavulanic acid   | 9.1  | 64.0 | NA   | NA   | NA   | NA   | NA   | NA   | 64.2 | 16.7 | NA   | NA   | NA   | NA   | NA   | NA   | 9.7  | 59.4 | NA   | NA   |
| Piperacillin-tazobactam       | 7.9  | 83.8 | 8.6  | 80.9 | 7.6  | 84.6 | 4.2  | 88.9 | 4.8  | 88.8 | 6.7  | 80.7 | 4.8  | 87.4 | 2.6  | 91.3 | 3.2  | 92.5 | 3.2  | 90.9 |
| Cefazolin                     | 72.8 | 5.8  | 64.1 | 19.9 | 72.9 | 14.3 | 72.5 | 14.6 | 71.5 | 9.5  | 74.6 | 11.9 | 73.9 | 25.4 | 63.4 | 20.9 | 64.6 | 20.6 | 59.3 | 25.9 |
| Cefoperazone                  | NA   | NA   | NA   | NA   | NA   | NA   | 66.9 | 26.8 | 46.9 | 36.8 | NA   | NA   | 64.7 | 26.5 | 100  | 0    | 51.9 | 42.4 | NA   | NA   |
| Cefuroxime                    | 67.7 | 30.1 | 58.1 | 38.7 | 65.2 | 32.7 | 62.7 | 35.3 | 55.7 | 39.1 | 66.8 | 30.6 | 60.1 | 38.7 | 58.6 | 40.3 | 56.0 | 41.7 | 53.5 | 44.7 |
| Ceftazidime                   | 39.3 | 53.7 | 28.7 | 64.5 | 52.3 | 41.5 | 32.3 | 60.5 | 25.6 | 66.5 | 28.8 | 61.8 | 30.7 | 66.6 | 21.4 | 69.5 | 18.1 | 74.1 | 19.2 | 73.6 |
| Ceftriaxone                   | 65.9 | 31.0 | NA   | NA   | NA   | NA   | NA   | NA   | 60.4 | 39.3 | 65.0 | 35.0 | 66.3 | 33.6 | NA   | NA   | 53.4 | 45.8 | NA   | NA   |
| Cefotaxime                    | 68.1 | 27.0 | 56.2 | 42.2 | 64.6 | 29.1 | 62.4 | 36.4 | 57.4 | 38.4 | 65.7 | 32.8 | 63.3 | 35.1 | 58.3 | 40.3 | 55.4 | 42.8 | 52.9 | 46.1 |
| Cefepime                      | 43.7 | 38.5 | 44.2 | 45.1 | 58.9 | 27.4 | 46.6 | 38.8 | 31.9 | 55.6 | 48.0 | 35.8 | 24.7 | 60.6 | 29.1 | 50.9 | 28.5 | 50.4 | 28.8 | 52.8 |
| Cefmetazole                   | 20.6 | 76.2 | 8.8  | 89.8 | NA   | NA   | NA   | NA   | 2.4  | 95.1 | 6.8  | 90.6 | 6.0  | 92.7 | 5.7  | 93.7 | 4.3  | 94.5 | 7.7  | 91.0 |
| Cefotetan                     | 4.7  | 92.8 | NA   | NA   | NA   | NA   | NA   | NA   | 2.3  | 96.7 | NA   | NA   | 1.6  | 96.9 | 6.0  | 92.6 | NA   | NA   | NA   | NA   |
| Cefoxitin                     | 15.2 | 77.3 | 16.8 | 70.7 | 20.3 | 74.4 | 10.7 | 83.0 | 17.9 | 72.8 | 18.1 | 72.5 | 10.1 | 84.4 | 6.7  | 90.2 | 9.4  | 83.0 | 8.2  | 86.7 |
| Cefaclor                      | 81.2 | 18.8 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 67.0 | 31.1 | NA   | NA   | 60.9 | 38.5 | 31.4 | 67.7 | 53.3 | 45.6 |
| Cefprozil                     | 40.5 | 52.4 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 67.3 | 29.7 | NA   | NA   | 59.4 | 38.7 | NA   | NA   | 47.1 | 50.2 |
| Aztreonam                     | 48.0 | 47.0 | NA   | NA   | NA   | NA   | 41.9 | 48.6 | 39.9 | 58.2 | 60.0 | 40.0 | 43.4 | 56.2 | NA   | NA   | 31.9 | 60.1 | NA   | NA   |
| Ertapenem                     | 0.9  | 90.7 | 4.3  | 93.7 | 2.3  | 76.6 | 0.9  | 97.7 | 1.1  | 98.8 | 3.0  | 94.4 | 1.3  | 98.4 | 1.4  | 97.7 | 0.7  | 98.5 | 1.3  | 97.7 |
| Imipenem                      | 2.0  | 94.2 | 2.9  | 95.2 | 4.0  | 79.0 | 0.6  | 98.6 | 2.1  | 94.2 | 1.4  | 97.5 | 1.0  | 98.6 | 1.0  | 96.7 | 0.4  | 98.1 | 0.4  | 98.9 |
| Meropenem                     | 2.1  | 95.9 | 2.3  | 97.0 | 3.4  | 80.8 | 0.7  | 98.4 | 2.3  | 95.8 | 1.7  | 97.2 | 1.1  | 98.8 | 0.8  | 98.1 | 0.3  | 99.3 | 0.5  | 98.7 |
| Panipenem                     | NA   | NA   | NA   | NA   | 0    | 98.7 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 0.5  | 99.0 | NA   | NA   | 0.2  | 99.5 |
| Amikacin                      | 9.8  | 87.1 | 7.6  | 86.4 | 9.5  | 85.3 | 5.6  | 91.9 | 6.9  | 89.9 | 9.5  | 85.4 | 3.2  | 96.0 | 2.7  | 95.1 | 6.9  | 90.1 | 7.1  | 89.9 |
| Gentamicin                    | 50.7 | 47.1 | 52.7 | 46.4 | 58.4 | 39.9 | 53.8 | 44.9 | 49.4 | 49.1 | 56.2 | 42.1 | 49.1 | 48.5 | 38.0 | 60.4 | 53.6 | 45.7 | 48.8 | 50.4 |
| Tobramycin                    | 22.5 | 49.9 | NA   | NA   | NA   | NA   | NA   | NA   | 16.6 | 54.8 | 57.9 | 21.1 | 30.3 | 50.2 | NA   | NA   | NA   | NA   | NA   | NA   |
| Ciprofloxacin                 | 64.2 | 32.4 | 74.5 | 20.5 | 71.5 | 26.0 | 62.6 | 34.2 | 66.9 | 30.0 | 70.1 | 26.0 | 59.3 | 39.6 | 28.4 | 66.3 | 64.4 | 33.4 | 61.2 | 35.2 |
| Levofloxacin                  | 60.8 | 36.3 | NA   | NA   | NA   | NA   | 60.8 | 37.1 | 62.7 | 34.7 | 64.5 | 32.3 | 57.4 | 40.5 | NA   | NA   | 62.4 | 35.5 | 59.5 | 37.4 |
| Trimethoprim-sulfamethoxazole | 70.2 | 28.8 | 63.9 | 35.0 | 81.0 | 16.7 | 68.9 | 29.9 | 58.7 | 40.1 | 65.5 | 33.3 | 66.8 | 24.0 | 56.6 | 42.8 | 67.2 | 31.7 | 59.4 | 39.5 |
| Nitrofurantoin                | 5.7  | 79.3 | NA   | NA   | NA   | NA   | 10.2 | 84.7 | 5.4  | 82.9 | 9.6  | 85.0 | 5.1  | 83.9 | NA   | NA   | 10.0 | 85.0 | NA   | NA   |
| Chloramphenicol               | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 16.4 | 77.6 | NA   | NA   | NA   | NA   | NA   | NA   | 29.9 | 65.4 | NA   | NA   |
| Tetracycline                  | 68.8 | 30.0 | NA   | NA   | NA   | NA   | 72.5 | 26.7 | NA   | NA   | NA   | NA   | 73.5 | 24.8 | NA   | NA   | NA   | NA   | NA   | NA   |
| Minocycline                   | 18.4 | 69.8 | NA   | NA   | NA   | NA   | NA   | NA   | 36.2 | 46.0 | 25.5 | 63.1 | NA   | NA   | NA   | NA   | 22.5 | 66.1 | NA   | NA   |
| Tigecycline                   | 2.1  | 96.4 | NA   | NA   | NA   | NA   | 0.5  | 98.6 | 0    | 99.6 | 0.4  | 98.2 | 0.4  | 97.8 | 0.1  | 99.9 | 0.1  | 99.6 | 0    | 98.2 |

表 2 ( 续 )  
Table 2 ( continued )

| Antibiotic                    | SCH  |      | SYF  |      | TJX  |      | XJH  |      | Z1   |      | SYH  |      | TJJ  |      | HXH  |      | NMH  |      | Total |      |
|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|------|
|                               | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R    | S    | R     | S    |
| Ampicillin                    | 85.3 | 10.8 | 83.2 | 15.6 | 93.0 | 5.3  | 88.9 | 9.9  | 88.2 | 10.2 | 85.6 | 13.6 | 84.1 | 14.3 | 88.1 | 10.8 | 87.3 | 11.0 | 87.3  | 11.0 |
| Piperacillin                  | 79.3 | 16.6 | NA   | NA   | 87.9 | 9.4  | 70.8 | 20.1 | 77.6 | 14.9 | 67.8 | 24.0 | NA   | NA   | NA   | NA   | 80.5 | 12.6 | 75.3  | 17.8 |
| Amoxicillin-clavulanic acid   | 16.5 | 42.1 | NA   | NA   | 18.3 | 44.4 | 11.0 | 58.8 | 34.6 | 27.9 | 13.7 | 56.2 | 12.2 | 62.8 | NA   | NA   | 11.2 | 57.6 | 16.6  | 51.5 |
| Cefoperazone-sulbactam        | 5.0  | 71.9 | 13.8 | 67.3 | 10.4 | 61.8 | 4.6  | 71.5 | 7.9  | 70.9 | NA   | NA   | 1.2  | 92.4 | 5.7  | 82.6 | 1.6  | 85.6 | 6.1   | 76.2 |
| Ampicillin-sulbactam          | 38.6 | 32.0 | 56.3 | 29.3 | 56.4 | 21.7 | 52.5 | 26.0 | 60.3 | 22.4 | 54.1 | 24.4 | NA   | NA   | 65.8 | 18.2 | 45.4 | 29.5 | 47.1  | 32.1 |
| Ticarcillin-clavulanic acid   | NA   | NA   | NA   | NA   | NA   | NA   | 13.5 | 63.5 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 11.8  | 58.1 |
| Piperacillin-tazobactam       | 4.1  | 86.4 | 2.8  | 93.6 | 6.1  | 86.2 | 2.4  | 90.6 | 10.7 | 72.2 | 4.3  | 91.9 | 2.8  | 93.6 | 3.4  | 91.5 | 0.9  | 96.0 | 4.6   | 87.9 |
| Cefazolin                     | 68.8 | 14.2 | 62.4 | 0    | 83.1 | 9.3  | 73.6 | 1.6  | 76.6 | 11.3 | 81.2 | 0.1  | 66.9 | 0    | NA   | NA   | 64.2 | 0    | 70.9  | 12.9 |
| Cefoperazone                  | NA   | NA   | 53.8 | 45.0 | NA   | NA   | NA   | NA   | 41.7 | 58.3 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 53.2  | 40.8 |
| Cefuroxime                    | 60.3 | 37.7 | 56.2 | 43.1 | 78.3 | 20.1 | 68.3 | 28.5 | 62.9 | 32.9 | 52.4 | 37.2 | NA   | NA   | NA   | NA   | 65.6 | 27.3 | 62.3  | 35.4 |
| Ceftazidime                   | 28.7 | 61.5 | 25.0 | 73.4 | 35.8 | 53.9 | 33.5 | 61.8 | 23.0 | 68.0 | 27.5 | 68.6 | 24.2 | 64.4 | 31.0 | 67.9 | 33.5 | 53.4 | 27.0  | 65.8 |
| Ceftriaxone                   | NA   | NA   | 57.0 | 42.7 | NA   | NA   | 66.0 | 33.7 | NA   | NA   | 55.1 | 44.8 | 59.9 | 39.8 | 62.7 | 37.2 | 59.5 | 40.2 | 59.9  | 39.3 |
| Cefotaxime                    | 61.1 | 36.5 | NA   | NA   | 77.8 | 21.8 | 69.5 | 27.6 | 60.1 | 37.0 | 66.1 | 33.9 | 48.3 | 47.1 | NA   | NA   | 50.0 | 41.7 | 61.6  | 36.5 |
| Cefepime                      | 43.2 | 40.5 | 22.0 | 65.6 | 52.6 | 25.0 | 30.3 | 54.3 | 42.1 | 40.4 | 34.9 | 56.7 | 22.1 | 66.8 | 20.8 | 67.7 | 13.6 | 74.6 | 35.3  | 47.9 |
| Cefmetazole                   | 4.8  | 93.4 | 5.3  | 92.4 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 6.7   | 91.7 |
| Cefotetan                     | NA   | NA   | 2.1  | 96.3 | NA   | NA   | 3.0  | 95.5 | NA   | NA   | 2.1  | 96.9 | NA   | NA   | NA   | NA   | NA   | NA   | 2.8   | 95.7 |
| Cefoxitin                     | 5.4  | 91.0 | 19.8 | 77.5 | 14.3 | 79.2 | 16.7 | 70.3 | 14.4 | 75.6 | NA   | NA   | 17.7 | 71.4 | NA   | NA   | 16.2 | 70.2 | 12.9  | 79.6 |
| Cefaclor                      | 61.6 | 36.4 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 58.8  | 40.0 |
| Cefprozil                     | 59.3 | 38.3 | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 58.8  | 38.7 |
| Aztreonam                     | NA   | NA   | 36.5 | 62.4 | 47.8 | 39.7 | 42.5 | 56.8 | 39.9 | 48.4 | 42.1 | 55.9 | 40.0 | 59.5 | 42.4 | 57.3 | 35.4 | 63.9 | 40.2  | 53.8 |
| Ertapenem                     | 1.4  | 95.7 | 1.8  | 97.5 | NA   | NA   | 2.2  | 95.4 | NA   | NA   | NA   | NA   | 1.5  | 97.4 | NA   | NA   | 0.6  | 98.7 | 1.5   | 95.9 |
| Imipenem                      | 2.0  | 94.8 | 1.4  | 98.1 | 0.8  | 98.9 | 1.3  | 97.1 | 1.1  | 96.7 | 0.3  | 99.5 | 0.7  | 97.6 | 1.1  | 98.5 | 0.2  | 98.8 | 1.1   | 97.0 |
| Meropenem                     | 1.0  | 98.2 | 1.2  | 98.5 | 0.9  | 99.0 | 1.5  | 96.2 | 1.1  | 98.1 | 0.4  | 99.3 | 2.1  | 90.6 | NA   | NA   | 0    | 100  | 1.0   | 97.8 |
| Panipenem                     | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 0.3   | 99.4 |
| Amikacin                      | 3.8  | 91.4 | 3.6  | 96.1 | 2.9  | 95.7 | 4.4  | 94.4 | 13.5 | 76.9 | 6.5  | 92.8 | 3.8  | 95.7 | 3.2  | 96.5 | 4.3  | 94.2 | 6.1   | 90.9 |
| Gentamicin                    | 42.4 | 56.3 | 45.9 | 53.5 | 48.2 | 50.9 | 49.4 | 49.3 | 60.2 | 38.3 | 52.4 | 46.9 | 50.9 | 48.5 | 46.3 | 53.1 | 55.0 | 44.4 | 50.0  | 48.8 |
| Tobramycin                    | NA   | NA   | 18.5 | 52.2 | 32.9 | 50.7 | 17.4 | 53.2 | NA   | NA   | 16.4 | 48.0 | 20.3 | 51.5 | 18.3 | 50.1 | 17.4 | 48.3 | 22.0  | 50.9 |
| Ciprofloxacin                 | 28.6 | 64.6 | 60.3 | 38.6 | 60.3 | 36.5 | 59.4 | 38.5 | 73.4 | 22.5 | 70.5 | 27.9 | 61.8 | 37.0 | 63.1 | 36.0 | 74.4 | 24.8 | 59.0  | 37.8 |
| Levofloxacin                  | NA   | NA   | 56.8 | 40.3 | 59.5 | 39.0 | 57.7 | 38.4 | 33.3 | 66.7 | 65.8 | 30.1 | 57.9 | 38.9 | 59.8 | 37.4 | 70.4 | 26.1 | 60.5  | 37.0 |
| Trimethoprim-sulfamethoxazole | 57.5 | 41.3 | 65.8 | 34.2 | 59.6 | 39.1 | 69.3 | 26.1 | 69.6 | 29.0 | 41.8 | 58.2 | 62.4 | 37.4 | 60.9 | 39.1 | 67.2 | 32.8 | 63.1  | 35.5 |
| Nitrofurantoin                | NA   | NA   | 5.1  | 82.7 | 5.1  | 88.3 | 5.8  | 81.7 | NA   | NA   | 6.8  | 79.6 | 5.2  | 81.6 | 5.6  | 79.8 | NA   | NA   | 6.3   | 82.6 |
| Chloramphenicol               | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 15.4 | 84.6 | 37.5 | 53.8 | NA   | NA   | NA   | NA   | NA   | NA   | 30.4  | 64.3 |
| Tetracycline                  | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 76.0 | 22.8 | 79.2 | 20.6 | 68.0 | 30.3 | NA   | NA   | NA   | NA   | 73.6  | 25.3 |
| Minocycline                   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | NA   | 16.7 | 75.0 | NA   | NA   | NA   | NA   | 20.1 | 70.6 | 38.3 | 31.2 | 22.1  | 66.0 |
| Tigecycline                   | 3.0  | 96.0 | NA   | NA   | 0.3  | 99.1 | 0    | 100  | NA   | NA   | NA   | NA   | 0.1  | 99.6 | 0.2  | 99.4 | 0.6  | 98.3 | 0.6   | 98.7 |

Some data were not included for the hospitals where only few strains were tested. The 95.3% resistance to meropenem from West China Hospital was excluded due to inaccurate data.

NA; not available; AYD: The First Affiliated Hospital of Anhui Medical University; BJH: Beijing Hospital; CQH: The First Affiliated Hospital of Chongqing Medical University; GSY: Gansu Provincial Hospital; GZH: The First Affiliated Hospital of Guangzhou Medical University; HSH: Huashan Hospital, Fudan University; KMH: First Affiliated Hospital of Kunming Medical University; PED: Children's Hospital of Fudan University; PUH: Peking Union Medical College Hospital; RJH: Rui Jin Hospital Shanghai Jiao Tong University School of Medicine; SCH: Children's Hospital of Shanghai; SYF: Sir Run Run Shaw Hospital, Zhejiang University School of Medicine; TJX: Tongji Medical College of Huazhong University of Science and Technology; XJH: The First Affiliated Hospital of Xinjiang Medical University; Z1: The First Affiliated Hospital, Zhejiang University; SYH: The First Hospital of China Medical University; TJJ: Tianjin Medical University General Hospital; HXH: West China Hospital, Sichuan University; NMH: Inner Mongolia Medical College Hospital.

表 3 全国 19 所医院不同年份大肠埃希菌对常见抗菌药物的平均耐药率和敏感率  
Table 3 Susceptibility of *E. coli* to antimicrobial agents in different years

(%)

| Antibiotic                    | 2005      |      | 2006      |      | 2007      |      | 2008      |      | 2009      |      | 2010      |      | 2011       |      | 2012       |      | 2013       |      | 2014       |      | Total      |      |      |
|-------------------------------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|------------|------|------------|------|------------|------|------------|------|------------|------|------|
|                               | (n=3 949) |      | (n=5 553) |      | (n=6 524) |      | (n=6 678) |      | (n=7 992) |      | (n=9 225) |      | (n=10 861) |      | (n=13 406) |      | (n=16 794) |      | (n=16 511) |      | (n=97 493) |      |      |
|                               | R         | S    | R         | S    | R         | S    | R         | S    | R         | S    | R         | S    | R          | S    | R          | S    | R          | S    | R          | S    | R          | S    |      |
| Ampicillin                    | 86.8      | 11.7 | 85.7      | 12.4 | 88.2      | 9.7  | 88.6      | 9.6  | 89.0      | 9.1  | 88.4      | 9.7  | 88.1       | 10.3 | 87.3       | 11.3 | 86.2       | 12.0 | 86.0       | 12.4 | 87.3       | 11.0 |      |
| Piperacillin                  | 77.3      | 15.8 | 76.3      | 17.1 | 76.0      | 16.4 | 77.1      | 16.2 | 76.9      | 16.5 | 75.3      | 18.0 | 76.3       | 18.4 | 76.7       | 17.5 | 73.5       | 18.6 | 71.6       | 20.5 | 75.3       | 17.8 |      |
| Amoxicillin-clavulanic acid   | 27.1      | 39.8 | 16.4      | 51.2 | 18.0      | 50.6 | 16.2      | 46.8 | 17.9      | 42.9 | 18.3      | 49.0 | 17.6       | 51.6 | 16.8       | 52.0 | 15.4       | 54.6 | 11.6       | 59.8 | 16.6       | 51.5 |      |
| Cefoperazone-sulbactam        | 9.8       | 69.0 | 5.7       | 77.4 | 2.9       | 84.3 | 4.0       | 82.8 | 5.3       | 77.6 | 6.5       | 75.4 | 7.9        | 72.4 | 7.8        | 73.3 | 6.0        | 75.9 | 5.4        | 76.2 | 6.1        | 76.2 |      |
| Ampicillin-sulbactam          | 49.4      | 32.1 | 47.9      | 31.3 | 48.4      | 29.8 | 43.1      | 34.9 | 46.4      | 32.3 | 44.3      | 34.6 | 46.7       | 32.6 | 44.4       | 34.3 | 48.7       | 30.6 | 50.3       | 29.8 | 47.1       | 32.1 |      |
| Ticarcillin-clavulanic acid   | 17.2      | 53.1 | 7.8       | 63.7 | 12.7      | 57.7 | 10.9      | 56.2 | 12.6      | 54.7 | 8.6       | 63.5 | 9.1        | 62.3 | 14.7       | 52.3 | 11.5       | 58.6 | 12.4       | 57.6 | 11.8       | 58.1 |      |
| Piperacillin-tazobactam       | 6.5       | 81.2 | 4.2       | 85.3 | 5.5       | 83.0 | 4.2       | 85.4 | 4.6       | 86.4 | 5.9       | 85.9 | 4.9        | 87.7 | 5.0        | 88.9 | 3.9        | 90.8 | 3.4        | 91.7 | 4.6        | 87.9 |      |
| Cefazolin                     | 68.8      | 14.2 | 66.5      | 17.5 | 70.2      | 15.5 | 70.6      | 15.9 | 72.7      | 15.4 | 71.8      | 16.3 | 71.4       | 13.9 | 70.4       | 10.6 | 72.8       | 9.9  | 71.1       | 7.5  | 70.9       | 12.9 |      |
| Cefoperazone                  | 45.7      | 38.0 | 53.5      | 41.6 | 52.7      | 41.8 | 54.3      | 40.9 | 52.6      | 40.2 | 55.2      | 39.6 | 50.8       | 42.8 | NA         | NA   | NA         | NA   | NA         | NA   | 53.2       | 40.8 |      |
| Cefuroxime                    | 52.8      | 42.7 | 55.5      | 41.6 | 61.6      | 36.0 | 63.0      | 34.7 | 63.9      | 34.2 | 64.1      | 33.7 | 64.1       | 34.1 | 62.9       | 34.8 | 64.4       | 34.0 | 62.8       | 34.7 | 62.3       | 35.4 |      |
| Ceftazidime                   | 14.9      | 76.7 | 17.0      | 74.5 | 19.9      | 70.4 | 22.6      | 67.6 | 28.5      | 63.2 | 30.7      | 60.5 | 31.3       | 62.2 | 30.1       | 63.0 | 28.4       | 66.1 | 28.8       | 66.2 | 27.0       | 65.8 |      |
| Ceftriaxone                   | 49.6      | 48.5 | 51.5      | 48.0 | 56.0      | 42.3 | 55.6      | 43.8 | 59.1      | 40.3 | 60.3      | 36.9 | 61.1       | 38.2 | 60.2       | 39.2 | 60.3       | 39.2 | 61.1       | 37.9 | 59.9       | 39.3 |      |
| Cefotaxime                    | 52.2      | 44.7 | 54.9      | 42.6 | 60.4      | 37.7 | 62.3      | 35.5 | 63.2      | 34.0 | 63.2      | 34.4 | 63.4       | 35.0 | 63.2       | 35.8 | 62.9       | 35.8 | 62.0       | 36.4 | 61.6       | 36.5 |      |
| Cefepime                      | 31.2      | 49.0 | 32.2      | 46.5 | 35.4      | 43.0 | 37.6      | 42.1 | 40.2      | 40.3 | 42.1      | 39.4 | 40.7       | 42.6 | 38.5       | 45.9 | 31.6       | 54.5 | 28.1       | 58.7 | 35.3       | 47.9 |      |
| Cefmetazole                   | NA        | NA   | 8.5       | 90.9 | NA        | NA   | 4.5       | 94.6 | 4.5       | 94.6 | 9.4       | 88.9 | 8.3        | 90.0 | 5.6        | 92.7 | 5.4        | 92.8 | 5.4        | 93.3 | 6.7        | 91.7 |      |
| Cefotetan                     | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA         | 95.9 | 2.3        | 96.2 | NA         | NA   | 3.2        | 95.4 | 2.8        | 95.7 |      |
| Cefoxitin                     | 13.3      | 78.1 | 11.6      | 81.7 | 10.8      | 81.6 | 10.9      | 82.0 | 10.9      | 82.4 | 13.5      | 79.8 | 12.4       | 82.4 | 15.5       | 76.8 | 16.3       | 75.5 | 13.6       | 76.6 | 12.9       | 79.6 |      |
| Cefaclor                      | 47.5      | 50.5 | 53.5      | 45.2 | 58.4      | 40.1 | 62.2      | 36.6 | 62.6      | 36.3 | 62.1      | 37.1 | 61.5       | 37.6 | NA         | NA   | 24.7       | 75.3 | 34.7       | 63.9 | 58.8       | 40.0 |      |
| Cefprozil                     | 50.1      | 45.9 | 54.1      | 42.9 | 60.9      | 37.3 | 63.6      | 34.3 | 73.0      | 26.0 | 54.2      | 40.7 | NA         | NA   | NA         | NA   | NA         | NA   | NA         | NA   | 58.8       | 38.7 |      |
| Aztreonam                     | 30.8      | 57.6 | 29.9      | 59.4 | 35.7      | 52.3 | 38.4      | 49.5 | 42.6      | 46.9 | 44.2      | 47.2 | 40.4       | 54.0 | 41.6       | 53.4 | 41.8       | 55.1 | 40.7       | 56.0 | 40.2       | 53.8 |      |
| Ertapenem                     | NA        | NA   | NA        | NA   | NA        | NA   | 1.2       | 96.1 | 1.2       | 95.7 | 96.1      | 92.9 | 2.2        | 93.6 | 1.5        | 97.5 | 1.6        | 96.8 | 1.2        | 96.4 | 1.5        | 95.9 |      |
| Imipenem                      | 1.1       | 95.0 | 1.4       | 95.1 | 0.7       | 96.6 | 1.2       | 96.2 | 1.7       | 94.1 | 1.6       | 94.2 | 0.9        | 98.2 | 0.9        | 98.2 | 1.0        | 98.6 | 0.9        | 98.5 | 1.1        | 97.0 |      |
| Meropenem                     | 1.4       | 97.2 | 0.8       | 97.6 | 0.8       | 97.9 | 0.9       | 97.8 | 1.0       | 96.6 | 1.4       | 95.4 | 1.1        | 98.1 | 1.0        | 98.5 | 1.1        | 98.5 | 1.0        | 98.8 | 1.0        | 97.8 |      |
| Panipenem                     | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | 0.3       | NA   | 0.3        | 99.2 | 0.2        | 99.4 | 0.4        | 99.5 | NA         | NA   | 0.3        | 99.4 |      |
| Amikacin                      | 12.0      | 82.1 | 8.1       | 87.6 | 8.0       | 87.5 | 8.2       | 87.7 | 7.6       | 89.0 | 7.4       | 89.1 | 5.6        | 91.3 | 5.4        | 92.0 | 4.0        | 94.1 | 4.0        | 94.4 | 6.1        | 90.9 |      |
| Gentamicin                    | 60.4      | 38.4 | 53.9      | 44.5 | 55.0      | 44.0 | 52.6      | 45.8 | 52.4      | 45.6 | 52.2      | 46.3 | 47.8       | 50.9 | 47.9       | 50.8 | 47.3       | 51.9 | 46.6       | 52.6 | 50.0       | 48.8 |      |
| Tobramycin                    | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA         | 47.5 | 23.8       | 50.9 | 21.1       | 51.0 | 19.0       | 52.1 | 22.0       | 50.9 |      |
| Ciprofloxacin                 | 68.2      | 28.6 | 60.2      | 36.7 | 59.2      | 37.0 | 58.7      | 37.3 | 58.7      | 37.7 | 59.5      | 36.9 | 57.2       | 38.3 | 57.8       | 38.3 | 58.3       | 39.4 | 58.9       | 39.2 | 59.0       | 37.8 |      |
| Levofloxacin                  | 62.2      | 35.0 | 63.0      | 33.1 | 60.6      | 36.4 | 64.5      | 33.0 | 65.9      | 32.0 | 64.2      | 33.6 | 60.2       | 37.8 | 60.6       | 37.0 | 59.0       | 38.6 | 58.7       | 38.3 | 60.5       | 37.0 |      |
| Trimethoprim-sulfamethoxazole | 70.8      | 27.9 | 64.7      | 33.9 | 66.5      | 32.3 | 64.7      | 34.0 | 66.2      | 31.2 | 66.8      | 31.0 | 66.6       | 30.3 | 61.5       | 37.7 | 57.6       | 41.8 | 59.1       | 40.5 | 63.1       | 35.5 |      |
| Nitrofurantoin                | 10.6      | 82.3 | 10.3      | 84.4 | 8.9       | 84.5 | 9.9       | 84.0 | 7.8       | 85.8 | 7.8       | 85.9 | 6.5        | 84.2 | 6.5        | 82.7 | 5.4        | 81.8 | 5.6        | 81.5 | 6.3        | 82.6 |      |
| Chloramphenicol               | 31.7      | 63.4 | 28.8      | 67.2 | 28.0      | 65.0 | NA        | NA   | NA        | NA   | NA        | NA   | NA         | NA   | 33.6       | 59.8 | 35.2       | 59.3 | 28.1       | 53.1 | 30.4       | 64.3 |      |
| Tetracycline                  | 75.0      | 23.6 | 77.6      | 21.5 | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA         | 77.0 | 20.9       | 76.0 | 23.0       | 71.4 | 27.8       | 70.9 | 28.4       | 73.6 | 25.3 |
| Minocycline                   | NA        | NA   | 26.3      | 61.4 | 24.2      | 63.8 | 22.8      | 61.5 | 61.5      | 62.2 | 24.0      | 63.8 | 18.0       | 70.7 | 23.2       | 62.5 | 22.0       | 66.2 | 20.6       | 69.4 | 22.1       | 66.0 |      |
| Tigecycline                   | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | NA        | NA   | 0.9       | 97.0 | 2.8        | 96.6 | 0.5        | 98.6 | 0.6        | 98.5 | 0.3        | 99.1 | 0.6        | 98.7 |      |

NA; not available.

表 4 不同科室患者临床分离大肠埃希菌对抗菌药物的耐药率和敏感率  
Table 4 Susceptibility of *E. coli* to antimicrobial agents in different departments

| Antibiotic                    | ( % )         |      |                    |      |                     |      |                        |      |
|-------------------------------|---------------|------|--------------------|------|---------------------|------|------------------------|------|
|                               | ICU (n=5 298) |      | Non-ICU (n=68 945) |      | Emergency (n=3 155) |      | Outpatients (n=20 091) |      |
|                               | R             | S    | R                  | S    | R                   | S    | R                      | S    |
| Ampicillin                    | 92.3          | 6.3  | 88.3               | 10.1 | 88.2                | 10.5 | 81.8                   | 15.7 |
| Piperacillin                  | 84.0          | 11.0 | 77.4               | 16.3 | 75.3                | 18.1 | 67.0                   | 24.0 |
| Amoxicillin-clavulanic acid   | 21.2          | 45.1 | 17.0               | 50.4 | 14.2                | 57.5 | 12.4                   | 59.4 |
| Cefoperazone-sulbactam        | 11.4          | 64.9 | 6.5                | 74.7 | 9.0                 | 74.1 | 3.2                    | 83.9 |
| Ampicillin-sulbactam          | 58.4          | 23.2 | 50.3               | 29.0 | 49.8                | 32.3 | 33.5                   | 44.2 |
| Ticarcillin-clavulanic acid   | 21.6          | 45.7 | 12.1               | 57.4 | 10.3                | 57.4 | 7.1                    | 66.6 |
| Piperacillin-tazobactam       | 8.6           | 81.6 | 4.8                | 87.3 | 5.8                 | 86.6 | 2.6                    | 91.6 |
| Cefazolin                     | 83.0          | 6.7  | 73.6               | 11.1 | 71.4                | 9.9  | 56.1                   | 22.3 |
| Cefoperazone                  | 66.0          | 30.3 | 53.4               | 40.4 | 55.1                | 38.6 | 44.5                   | 49.4 |
| Cefuroxime                    | 78.1          | 20.2 | 66.0               | 31.6 | 62.8                | 34.8 | 48.2                   | 49.6 |
| Ceftazidime                   | 36.5          | 55.2 | 28.9               | 63.8 | 28.4                | 64.6 | 18.0                   | 75.2 |
| Ceftriaxone                   | 72.3          | 26.9 | 60.0               | 39.2 | 60.2                | 38.8 | 50.6                   | 48.0 |
| Cefotaxime                    | 76.9          | 22.0 | 65.4               | 32.6 | 63.3                | 35.2 | 47.7                   | 50.4 |
| Cefepime                      | 44.9          | 37.0 | 37.2               | 45.7 | 34.2                | 50.1 | 26.4                   | 57.9 |
| Cefmetazole                   | 9.9           | 88.1 | 7.6                | 90.5 | 7.5                 | 90.9 | 4.4                    | 94.6 |
| Cefotetan                     | 8.1           | 89.7 | 2.7                | 95.8 | 1.2                 | 98.3 | 1.2                    | 97.7 |
| Cefoxitin                     | 17.9          | 73.3 | 13.4               | 78.7 | 13.0                | 79.3 | 8.8                    | 85.8 |
| Cefaclor                      | 83.7          | 15.6 | 67.1               | 31.6 | 69.2                | 29.7 | 44.0                   | 54.9 |
| Cefprozil                     | 87.1          | 11.3 | 67.8               | 30.1 | 74.4                | 23.3 | 41.7                   | 55.2 |
| Aztreonam                     | 49.1          | 45.9 | 40.7               | 53.2 | 36.8                | 57.7 | 30.7                   | 63.1 |
| Ertapenem                     | 4.2           | 92.5 | 1.4                | 95.7 | 3.8                 | 93.3 | 0.6                    | 97.8 |
| Imipenem                      | 3.3           | 94.3 | 1.1                | 96.9 | 1.9                 | 96.8 | 0.5                    | 97.9 |
| Meropenem                     | 3.4           | 94.8 | 1.4                | 97.3 | 2.1                 | 98.9 | 0.4                    | 98.8 |
| Panipenem                     | 3.7           | 94.8 | 0.3                | 99.0 | 0.7                 | 99.3 | 0                      | 99.9 |
| Amikacin                      | 8.4           | 88.4 | 6.5                | 90.5 | 6.9                 | 89.9 | 4.3                    | 92.7 |
| Gentamicin                    | 54.7          | 44.4 | 51.3               | 47.4 | 53.8                | 45.1 | 44.5                   | 54.4 |
| Tobramycin                    | 26.3          | 46.7 | 21.6               | 50.9 | 19.2                | 50.0 | 23.2                   | 53.8 |
| Ciprofloxacin                 | 65.3          | 31.7 | 61.0               | 36.0 | 66.4                | 31.5 | 50.1                   | 45.9 |
| Levofloxacin                  | 64.9          | 32.5 | 60.6               | 36.8 | 60.0                | 38.1 | 57.6                   | 39.7 |
| Trimethoprim-sulfamethoxazole | 67.3          | 31.7 | 64.3               | 34.2 | 67.6                | 31.1 | 57.8                   | 41.2 |
| Nitrofurantoin                | 6.8           | 79.5 | 6.3                | 82.3 | 4.6                 | 84.9 | 6.4                    | 85.5 |
| Chloramphenicol               | 37.5          | 55.6 | 29.9               | 65.1 | 29.3                | 62.4 | 25.5                   | 71.6 |
| Tetracycline                  | 75.4          | 24.0 | 74.1               | 24.7 | 73.5                | 26.1 | 67.0                   | 32.0 |
| Minocycline                   | 28.9          | 60.2 | 22.5               | 65.3 | 22.7                | 65.7 | 18.2                   | 70.7 |
| Tigecycline                   | 0.5           | 98.2 | 0.6                | 98.7 | 0.7                 | 98.7 | 0.3                    | 99.1 |

表 5 不同来源标本大肠埃希菌对抗菌药物的耐药率和敏感率  
Table 5 Susceptibility of the *E. coli* strains isolated from different specimens

( % )

| Antibiotic                    | Urine<br>(n=48 515) |      | Respiratory<br>tract<br>(n=15 377) |      | Secretions,<br>abscess, wound<br>(n=8 776) |      | Blood<br>(n=9 694) |      | Feces<br>(n=2 311) |      | Catheter<br>(n=348) |      | Aseptic<br>body fluid<br>(n=4 364) |      | Cerebrospinal<br>fluid (n=248) |      | Other<br>(n=7 860) |      |
|-------------------------------|---------------------|------|------------------------------------|------|--------------------------------------------|------|--------------------|------|--------------------|------|---------------------|------|------------------------------------|------|--------------------------------|------|--------------------|------|
|                               | R                   | S    | R                                  | S    | R                                          | S    | R                  | S    | R                  | S    | R                   | S    | R                                  | S    | R                              | S    | R                  | S    |
| Ampicillin                    | 85.6                | 12.5 | 92.7                               | 5.9  | 88.5                                       | 9.8  | 88.3               | 10.5 | 91.9               | 6.9  | 91.6                | 4.9  | 83.5                               | 14.0 | 89.0                           | 8.4  | 84.3               | 13.8 |
| Piperacillin                  | 73.0                | 19.3 | 83.9                               | 11.7 | 77.4                                       | 16.2 | 77.9               | 15.7 | 82.6               | 12.7 | 81.8                | 10.2 | 73.6                               | 19.6 | 81.9                           | 13.5 | 64.8               | 26.7 |
| Amoxicillin-clavulanic acid   | 15.8                | 51.5 | 19.6                               | 45.2 | 15.6                                       | 50.8 | 15.9               | 51.4 | 24.5               | 38.9 | 22.2                | 44.4 | 22.1                               | 47.9 | 13.2                           | 44.6 | 10.7               | 68.9 |
| Cefoperazone-sulbactam        | 5.4                 | 77.9 | 8.1                                | 69.2 | 5.5                                        | 76.7 | 6.6                | 75.7 | 9.5                | 70.4 | 8.8                 | 69.9 | 8.7                                | 73.5 | 8.0                            | 74.2 | 4.1                | 83.9 |
| Ampicillin-sulbactam          | 44.4                | 34.5 | 56.1                               | 22.7 | 48.6                                       | 30.0 | 51.6               | 27.9 | 55.8               | 24.7 | 52.3                | 26.3 | 51.3                               | 30.7 | 54.3                           | 23.3 | 32.7               | 47.2 |
| Ticarcillin-clavulanic Acid   | 12.1                | 56.4 | 19.3                               | 44.2 | 9.6                                        | 55.3 | 13.6               | 54.5 | 16.5               | 48.0 | 16.7                | 50.0 | 16.2                               | 53.4 | NA                             | NA   | 6.4                | 70.6 |
| Piperacillin-tazobactam       | 3.7                 | 89.1 | 6.8                                | 83.2 | 4.6                                        | 88.5 | 4.9                | 88.3 | 7.8                | 81.4 | 6.2                 | 83.6 | 6.0                                | 86.0 | 7.7                            | 83.3 | 3.0                | 92.1 |
| Cefazolin                     | 66.7                | 14.6 | 83.3                               | 8.2  | 71.9                                       | 11.2 | 73.7               | 10.5 | 81.7               | 7.4  | 81.3                | 6.4  | 69.3                               | 11.8 | 80.9                           | 7.5  | 62.2               | 19.9 |
| Cefoperazone                  | 53.1                | 40.2 | 66.5                               | 27.6 | 57.6                                       | 33.9 | 56.5               | 37.8 | 64.4               | 30.4 | 70.4                | 18.5 | 61.1                               | 36.1 | NA                             | NA   | 36.7               | 57.9 |
| Cefuroxime                    | 58.0                | 39.5 | 76.5                               | 21.6 | 64.6                                       | 33.6 | 65.1               | 33.1 | 74.0               | 23.7 | 76.7                | 20.9 | 62.8                               | 34.5 | 75.1                           | 23.3 | 50.4               | 47.5 |
| Ceftazidime                   | 25.1                | 68.2 | 33.5                               | 56.7 | 28.3                                       | 64.9 | 29.6               | 64.2 | 32.7               | 58.6 | 31.8                | 57.6 | 29.7                               | 63.8 | 34.7                           | 53.7 | 17.1               | 76.5 |
| Ceftriaxone                   | 58.3                | 40.8 | 74.3                               | 25.0 | 64.4                                       | 34.8 | 62.2               | 37.2 | 69.3               | 30.3 | 73.5                | 26.5 | 57.5                               | 41.3 | 75.9                           | 24.1 | 45.1               | 54.1 |
| Cefotaxime                    | 56.9                | 41.0 | 76.2                               | 22.3 | 64.7                                       | 33.4 | 65.2               | 33.0 | 72.9               | 25.8 | 76.6                | 22.4 | 61.3                               | 36.5 | 76.7                           | 22.3 | 48.8               | 49.4 |
| Cefepime                      | 33.1                | 51.4 | 45.9                               | 33.2 | 35.2                                       | 47.3 | 34.7               | 49.1 | 46.1               | 33.8 | 39.8                | 35.8 | 34.4                               | 49.8 | 50.8                           | 33.3 | 25.1               | 58.1 |
| Cefmetazole                   | 6.1                 | 92.4 | 10.1                               | 87.8 | 7.5                                        | 91.0 | 7.5                | 90.5 | 7.6                | 90.8 | 8.3                 | 91.7 | 6.6                                | 91.7 | 7.1                            | 91.4 | 4.5                | 94.4 |
| Cefotetan                     | 2.8                 | 96.0 | 4.1                                | 94.7 | 2.5                                        | 95.4 | 2.3                | 95.7 | 1.5                | 95.5 | 13.5                | 86.5 | 3.3                                | 94.9 | NA                             | NA   | 1.8                | 97.4 |
| Cefoxitin                     | 13.2                | 78.6 | 14.4                               | 78.8 | 11.9                                       | 82.4 | 11.2               | 81.1 | 15.8               | 74.7 | 17.2                | 71.9 | 14.9                               | 76.9 | 14.9                           | 80.2 | 9.2                | 84.8 |
| Cefaclor                      | 52.3                | 46.5 | 76.7                               | 22.1 | 57.8                                       | 41.2 | 66.7               | 32.2 | 70.8               | 27.9 | 79.1                | 18.7 | 54.5                               | 44.2 | 66.2                           | 33.8 | 53.2               | 45.6 |
| Cefprozil                     | 52.4                | 44.7 | 76.1                               | 22.3 | 58.8                                       | 38.8 | 62.2               | 36.2 | 58.3               | 36.9 | 76.7                | 23.3 | 52.6                               | 45.9 | 68.0                           | 30.0 | 61.0               | 36.0 |
| Aztreonam                     | 39.3                | 55.5 | 47.3                               | 44.2 | 38.9                                       | 54.7 | 41.1               | 53.9 | 48.2               | 43.5 | 46.1                | 44.8 | 42.8                               | 51.9 | 57.4                           | 38.9 | 27.6               | 66.4 |
| Ertapenem                     | 1.2                 | 96.4 | 3.3                                | 93.5 | 1.2                                        | 94.9 | 0.9                | 96.1 | 2.1                | 94.5 | 2.7                 | 95.3 | 1.5                                | 95.5 | 2.8                            | 94.4 | 0.8                | 98.4 |
| Imipenem                      | 0.8                 | 97.6 | 2.1                                | 95.3 | 1.3                                        | 96.7 | 0.9                | 97.3 | 1.2                | 96.5 | 2.3                 | 96.2 | 0.9                                | 96.8 | 2.1                            | 95.0 | 0.7                | 97.4 |
| Meropenem                     | 1.0                 | 98.0 | 2.0                                | 96.4 | 1.6                                        | 97.0 | 2.5                | 96.3 | 1.3                | 97.3 | 3.1                 | 95.1 | 1.6                                | 97.2 | 2.7                            | 95.9 | 0.7                | 98.6 |
| Panipenem                     | 0.1                 | 99.6 | 1.1                                | 98.2 | 0.6                                        | 98.9 | 0.6                | 99.2 | 0                  | 99.3 | 0                   | 100  | 0.6                                | 98.9 | 0                              | 100  | 0.4                | 99.1 |
| Amikacin                      | 5.7                 | 91.4 | 7.5                                | 89.0 | 6.0                                        | 91.3 | 6.1                | 90.9 | 9.0                | 86.4 | 7.6                 | 88.5 | 6.1                                | 91.9 | 3.7                            | 94.2 | 5.4                | 91.8 |
| Gentamicin                    | 48.6                | 50.2 | 51.7                               | 46.9 | 53.8                                       | 44.9 | 52.1               | 46.9 | 58.7               | 40.7 | 51.6                | 47.8 | 47.4                               | 51.4 | 43.0                           | 54.5 | 47.8               | 51.2 |
| Tobramycin                    | 21.2                | 52.2 | 27.1                               | 47.9 | 22.6                                       | 49.2 | 22.0               | 48.8 | 26.2               | 47.1 | 24.6                | 58.5 | 16.5                               | 58.0 | 26.5                           | 41.2 | 18.6               | 49.1 |
| Ciprofloxacin                 | 59.9                | 37.0 | 58.6                               | 38.1 | 57.1                                       | 39.2 | 62.0               | 35.5 | 68.7               | 27.8 | 55.7                | 40.5 | 58.9                               | 37.1 | 57.4                           | 38.9 | 49.3               | 47.6 |
| Levofloxacin                  | 63.8                | 33.4 | 61.3                               | 36.6 | 57.6                                       | 39.6 | 60.2               | 37.4 | 66.5               | 31.2 | 53.8                | 43.4 | 57.6                               | 39.4 | 62.3                           | 34.0 | 48.2               | 49.7 |
| Trimethoprim-sulfamethoxazole | 61.3                | 37.3 | 64.9                               | 33.5 | 68.2                                       | 30.7 | 64.8               | 33.9 | 71.8               | 27.4 | 69.8                | 29.6 | 60.7                               | 38.3 | 73.6                           | 25.0 | 61.9               | 36.7 |
| Nitrofurantoin                | 6.5                 | 83.7 | 8.7                                | 75.6 | 4.9                                        | 80.4 | 4.3                | 82.5 | 4.4                | 80.3 | 4.8                 | 88.1 | 6.5                                | 78.6 | 3.8                            | 92.3 | 6.2                | 82.2 |
| Chloramphenicol               | 24.8                | 69.4 | 33.0                               | 62.6 | 33.3                                       | 59.8 | 31.9               | 61.4 | 26.9               | 64.5 | 45.8                | 45.8 | 43.8                               | 52.3 | NA                             | NA   | 28.8               | 67.1 |
| Tetracycline                  | 73.1                | 25.7 | 71.5                               | 27.7 | 76.1                                       | 22.4 | 75.8               | 23.3 | 83.1               | 15.7 | 68.2                | 31.8 | 69.7                               | 28.8 | 90.0                           | 10.0 | 73.0               | 25.3 |
| Minocycline                   | 22.6                | 65.9 | 28.1                               | 58.7 | 24.9                                       | 60.2 | 18.6               | 70.1 | 26.6               | 62.4 | 23.8                | 66.7 | NA                                 | NA   | 21.4                           | 71.4 | 17.6               | 71.8 |
| Tigecycline                   | 0.6                 | 98.6 | 0.8                                | 98.1 | 0.9                                        | 98.6 | 0.1                | 99.2 | 1.4                | 98.3 | 4.3                 | 95.7 | NA                                 | NA   | 0                              | 94.7 | 0.1                | 99.5 |

NA; not available.

药性 不同年龄分离株的耐药率基本符合 65 岁及以上 >18~64 岁>17 岁及以下。17 岁及以下患者分离株对各类抗菌药物的敏感性都较高；65 岁及以上患者分离株对大部分抗菌药物耐药率较高，但对氨苄西林-舒巴坦的耐药率（7.8%）远低于其他患者，见表 6。

表 6 不同年龄患者分离菌株对抗菌药物的耐药率和敏感率  
Table 6 Susceptibility of the *E. coli* strains in terms of patient age

| Antibiotic                    | ( % )      |      |             |      |            |      |
|-------------------------------|------------|------|-------------|------|------------|------|
|                               | ≤ 17 years |      | 18-64 years |      | ≥ 65 years |      |
|                               | R          | S    | R           | S    | R          | S    |
| Ampicillin                    | 86.7       | 10.9 | 86.8        | 11.6 | 88.5       | 9.9  |
| Piperacillin                  | 73.8       | 19.8 | 74.7        | 18.0 | 77.4       | 16.0 |
| Amoxicillin-clavulanic acid   | 14.4       | 53.5 | 16.6        | 51.3 | 18.9       | 49.0 |
| Cefoperazone-sulbactam        | 4.4        | 77.1 | 0           | 0.1  | 0          | 0    |
| Ampicillin-sulbactam          | 37.7       | 36.0 | 48.0        | 32.4 | 7.8        | 73.3 |
| Ticarcillin-clavulanic acid   | 6.0        | 72.1 | 12.3        | 57.8 | 16.3       | 52.4 |
| Piperacillin-tazobactam       | 3.4        | 89.5 | 4.6         | 88.3 | 5.6        | 86.0 |
| Cefazolin                     | 68.8       | 16.2 | 70.7        | 11.9 | 73.7       | 10.4 |
| Cefoperazone                  | 38.0       | 55.1 | 53.7        | 40.3 | 56.9       | 36.5 |
| Cefuroxime                    | 62.0       | 36.5 | 61.6        | 36.3 | 65.1       | 31.7 |
| Ceftazidime                   | 24.6       | 66.8 | 27.0        | 66.4 | 29.8       | 63.1 |
| Ceftriaxone                   | 55.5       | 43.5 | 59.3        | 39.8 | 62.1       | 37.2 |
| Cefotaxime                    | 61.8       | 36.6 | 60.6        | 37.6 | 64.2       | 33.9 |
| Cefepime                      | 34.4       | 46.8 | 34.5        | 49.4 | 37.7       | 46.4 |
| Cefmetazole                   | 5.8        | 93.1 | 7.1         | 91.2 | 8.2        | 89.9 |
| Cefotetan                     | 4.8        | 94.0 | 2.1         | 96.5 | 3.3        | 95.3 |
| Cefoxitin                     | 8.2        | 88.0 | 13.1        | 78.9 | 16.9       | 74.0 |
| Cefaclor                      | 61.5       | 37.5 | 53.6        | 45.2 | 63.0       | 35.3 |
| Cefprozil                     | 61.4       | 36.8 | 55.9        | 41.5 | 63.9       | 32.9 |
| Aztreonam                     | 37.1       | 54.5 | 40.2        | 54.0 | 42.8       | 52.2 |
| Ertapenem                     | 1.3        | 96.9 | 1.2         | 96.1 | 2.1        | 94.9 |
| Imipenem                      | 1.2        | 96.6 | 0.9         | 97.5 | 1.3        | 97.0 |
| Meropenem                     | 1.0        | 98.1 | 1.3         | 97.7 | 1.6        | 97.1 |
| Panipenem                     | 0.4        | 99.0 | 0.2         | 99.5 | 0.2        | 99.5 |
| Amikacin                      | 3.2        | 94.0 | 6.7         | 90.5 | 7.1        | 89.6 |
| Gentamicin                    | 41.2       | 57.4 | 51.6        | 47.3 | 52.2       | 46.7 |
| Tobramycin                    | 20.6       | 54.7 | 22.1        | 50.9 | 21.0       | 51.4 |
| Ciprofloxacin                 | 31.3       | 63.6 | 62.7        | 34.4 | 71.5       | 26.0 |
| Levofloxacin                  | 36.2       | 62.0 | 60.6        | 37.0 | 66.3       | 30.8 |
| Trimethoprim-sulfamethoxazole | 57.5       | 41.4 | 64.6        | 34.0 | 63.7       | 34.6 |
| Nitrofurantoin                | 4.7        | 84.4 | 6.0         | 83.4 | 7.0        | 81.1 |
| Chloramphenicol               | 20.0       | 80.0 | 36.0        | 56.9 | 29.9       | 64.4 |
| Tetracycline                  | 70.2       | 28.9 | 74.0        | 24.7 | 73.7       | 25.3 |
| Minocycline                   | 16.8       | 74.6 | 21.2        | 66.3 | 24.1       | 64.0 |
| Tigecycline                   | 0.6        | 98.6 | 0.5         | 98.8 | 0.6        | 98.6 |

**2.4.5 产和非产 ESBL 大肠埃希菌的耐药性比较** 产 ESBL 大肠埃希菌对大多数抗菌药物的耐药率明显高于非产 ESBL 菌株。产 ESBL 大肠埃希菌对头孢哌酮-舒巴坦、哌拉西林-他唑巴坦、头孢美唑、头孢替坦、厄他培南、亚胺培南、美罗培南、帕尼培南、阿米卡星、呋喃妥因、替加环素的耐药率均低于 10%。非产 ESBL 大肠埃希菌除了对氨苄西林的耐药率为 70.5%，对四环素耐药率为 65.4% 外，对其余 33 种抗菌药物的耐药率都低于 50%，见表 7。

3 讨论

大肠埃希菌是临床分离最多，能引起人体各部位感染的最常见病原菌，对其耐药性监测及机制研究均有重要意义。CHINET 细菌耐药性监测结果显示，10 年间大肠埃希菌主要分离自住院患者（75.5%），其菌株主要来源于尿液（49.8%），其次是呼吸道（15.8%）和血液（9.9%）标本。

19 所医院大肠埃希菌的耐药性分析结果显示，不同医院的菌株耐药性各具特点，不同的耐药特点可能与各医院临床所应用抗菌药物的品种和数量有关，因此各医院的细菌耐药监测结果对指导本单位合理选用抗菌药物最具参考价值。

从 10 年总的耐药性分析结果来看，大肠埃希菌对多种常见抗菌药物的耐药率较高，其中对氨

苄西林（87.3%）、哌拉西林（75.3%）的耐药率最高，对头孢唑林、头孢呋辛、头孢噻肟、左氧氟沙星、甲氧苄啶-磺胺甲噁唑、四环素的耐药率均>60%。但大肠埃希菌对碳青霉烯类抗生素仍有较高的敏感率（>90%），提示该类药物仍可以作为治疗由产 ESBL 菌株所致重症感染时的首选经验药物之一。

2005—2014 年，大肠埃希菌对抗菌药物的耐药性不断发生变化。对头孢呋辛、头孢噻肟、头孢曲松、头孢他啶的耐药率 10 年间呈稳定上升趋势，LAI 等<sup>[3]</sup>对 2004—2012 年大肠埃希菌的耐药监测结果以及 YANG 等<sup>[4]</sup>对 2002—2012 年大肠埃希菌的耐药监测也得出同样的结论。这可能与第二、第三代头孢菌素在临床广泛使用有关。对阿莫西林-克拉维酸、阿米卡星、庆大霉素、妥布霉素、甲氧苄啶-磺胺甲噁唑和呋喃妥因等抗菌药物的耐药率却有缓慢下降趋势，其下降原因有待进一步研究。此外，监测数据还显示大肠埃希菌对呋喃妥因的耐药率较低，由于该药物血清浓度低，尿中的浓度较高，其带给大肠埃希菌的选择性压力较小<sup>[5]</sup>。提示该药仍然对大肠埃希菌引起的尿路感染有较好的作用。氟喹诺酮类抗菌药物的耐药率 10 年间基本保持稳定状态，细菌对其耐药率在 60% 左右，因此应用该类药物治疗大肠埃希菌引起的感染时，应根据具体的药敏结果进行选择用药。

表 7 产和非产 ESBL 大肠埃希菌对常见抗菌药物的耐药率和敏感率比较  
Table 7 Susceptibility of ESBLs (+) and ESBLs (-) strains of *E. coli* to antimicrobial agents

| Antibiotic                  | ESBL(+) <i>E. coli</i> |      | ESBL(-) <i>E. coli</i> |      | <i>P</i> value |
|-----------------------------|------------------------|------|------------------------|------|----------------|
|                             | R/%                    | S/%  | R/%                    | S/%  |                |
| Ampicillin                  | 99.2                   | 0.4  | 70.5                   | 25.8 | <0.01          |
| Piperacillin                | 97.0                   | 1.1  | 43.0                   | 42.5 | <0.01          |
| Amoxicillin-clavulanic acid | 19.1                   | 39.5 | 11.6                   | 72.2 | <0.01          |
| Cefoperazone-sulbactam      | 9.1                    | 63.1 | 2.8                    | 93.1 | <0.01          |
| Ampicillin-sulbactam        | 66.9                   | 11.8 | 23.7                   | 56.7 | <0.01          |
| Ticarcillin-clavulanic acid | 16.7                   | 38.3 | 4.6                    | 82.5 | <0.01          |
| Piperacillin-tazobactam     | 5.6                    | 84.4 | 3.7                    | 92.6 | <0.01          |
| Cefazolin                   | 99.0                   | 0.4  | 29.2                   | 28.8 | <0.01          |
| Cefoperazone                | 91.6                   | 1.8  | 4.8                    | 90.3 | <0.01          |
| Cefuroxime                  | 98.1                   | 1.5  | 13.1                   | 82.1 | <0.01          |
| Ceftazidime                 | 44.9                   | 45.1 | 6.0                    | 92.4 | <0.01          |
| Ceftriaxone                 | 97.9                   | 1.7  | 7.1                    | 91.7 | <0.01          |
| Cefotaxime                  | 98.3                   | 1.3  | 10.3                   | 85.7 | <0.01          |

表 7 (续)  
Table 7 (continued)

| Antibiotic                    | ESBL(+) <i>E. coli</i> |      | ESBL(-) <i>E. coli</i> |      | <i>P</i> value |
|-------------------------------|------------------------|------|------------------------|------|----------------|
|                               | R/%                    | S/%  | R/%                    | S/%  |                |
| Cefepime                      | 57.1                   | 19.5 | 5.2                    | 90.5 | <0.01          |
| Cefmetazole                   | 8.6                    | 89.4 | 4.5                    | 94.5 | <0.01          |
| Cefotetan                     | 2.0                    | 96.6 | 3.7                    | 94.5 | <0.01          |
| Cefoxitin                     | 16.6                   | 73.1 | 9.3                    | 86.8 | <0.01          |
| Cefaclor                      | 99.0                   | 0.9  | 13.6                   | 84.3 | <0.01          |
| Cefprozil                     | 99.2                   | 0.6  | 10.1                   | 81.7 | <0.01          |
| Aztreonam                     | 62.9                   | 28.4 | 5.7                    | 93.0 | <0.01          |
| Ertapenem                     | 1.4                    | 95.3 | 1.0                    | 97.7 | <0.01          |
| Imipenem                      | 0.9                    | 97.3 | 1.2                    | 97.4 | <0.01          |
| Meropenem                     | 1.0                    | 97.7 | 0.9                    | 98.6 | >0.05          |
| Panipenem                     | 0                      | 99.2 | 0.9                    | 98.6 | <0.01          |
| Amikacin                      | 7.7                    | 89.2 | 2.8                    | 95.5 | <0.01          |
| Gentamicin                    | 59.0                   | 39.8 | 36.5                   | 62.4 | <0.01          |
| Tobramycin                    | 29.5                   | 41.8 | 10.9                   | 65.5 | <0.01          |
| Ciprofloxacin                 | 73.2                   | 24.0 | 41.6                   | 55.4 | <0.01          |
| Levofloxacin                  | 73.2                   | 24.5 | 39.6                   | 57.9 | <0.01          |
| Trimethoprim-sulfamethoxazole | 71.7                   | 27.0 | 51.1                   | 47.6 | <0.01          |
| Nitrofurantoin                | 7.0                    | 80.2 | 4.7                    | 86.7 | <0.01          |
| Chloramphenicol               | 43.9                   | 48.1 | 11.8                   | 85.3 | <0.01          |
| Tetracycline                  | 78.9                   | 20.1 | 65.4                   | 33.8 | <0.01          |
| Minocycline                   | 25.8                   | 60.9 | 15.2                   | 75.3 | <0.01          |
| Tigecycline                   | 0.7                    | 98.5 | 0.4                    | 98.9 | <0.05          |

The data of ESBLs detection are not available for Rui Jin Hospital Shanghai Jiao Tong University School of Medicine.

不同科室分离大肠埃希菌的耐药率比较显示,ICU 来源的菌株对各抗菌药物的耐药率明显高于其他科室,这可能与 ICU 患者原发病常较重,抢救过程中常需气管插管、机械通气,长期激素和大量广谱抗菌药物的应用有关。

本次监测结果表明,10 年来,产 ESBL 大肠埃希菌检出率总体呈上升趋势(7.2%→55.4%),总检出率为 51.3%。此外,结果还显示,住院患者分离菌株的 ESBL 检出率高于门诊患者;不同科室中 ICU 分离株的 ESBL 检出率也高于其他科室。相比于其他国家,欧洲耐药监测网(the European Resistance Surveillance Network,EARS-net)曾报道,欧洲产 ESBL 大肠埃希菌的检出率从 2004 年的 9.7% 增长到 2010 年的 16.1%<sup>[6]</sup>,远低于中国产 ESBL 大肠埃希菌的检出率。本次耐药监测结果中,

新生儿中产 ESBL 大肠埃希菌的检出率为 45.8%(242/529),而在欧洲新生儿病房中产 ESBL 大肠埃希菌却鲜见报道<sup>[7]</sup>。此外,结果还显示门诊患者分离的菌株 ESBL 检出率高达 29.8%,这可能会改变门诊患者感染大肠埃希菌的用药方案,应引起我们的高度重视。

大肠埃希菌中产 ESBL 株对青霉素类、头孢菌素类、单环 β 内酰胺类抗生素的耐药率均明显高于非产酶株;此外产酶株对氨基糖苷类(庆大霉素 59.0%、妥布霉素 29.5%)和氟喹诺酮类抗菌药物(环丙沙星 73.2%、左氧氟沙星 73.2%)的耐药率也高于非产酶株(庆大霉素 36.5%、妥布霉素 10.9%、环丙沙星 41.6%、左氧氟沙星 39.6%),这可能与产 ESBL 菌株常携带其他耐药基因如 AmpC 酶(DHA-1)、氨基糖苷类钝化酶和喹诺酮类药物

耐药基因[*qnr* 和 *aac*(6')-Ib-cr]等有关<sup>[8]</sup>。以往文献报道大肠埃希菌主要耐药机制是产 ESBL, 此机制造成的耐药占总耐药株的 80%<sup>[9]</sup>。根据 YU 等<sup>[10]</sup>和卓超等<sup>[11]</sup>报道, 我国临床分离的大肠埃希菌产生的 ESBL 主要为 CTX-M-14 和 CTX-M-15 基因型。这些耐药基因常由质粒介导, 可在不同菌株、不同科室、不同地区间传播, 对这些产 ESBL 菌, 应进一步加强医院感染防控措施, 以防止其播散。ESBL 能被  $\beta$  内酰胺酶抑制剂所抑制, 所以产酶菌株对酶抑制剂复方制剂的耐药率除氨苄西林-舒巴坦 >60% 外, 其他均 <20%, 提示酶抑制剂复方制剂仍然可以作为治疗产 ESBL 菌株的经验用药选择之一。产酶株和非产酶株对碳青霉烯类抗生素均保持高度的敏感性, 耐药率 0~1.4%, 因此, 碳青霉烯类抗生素仍然是目前治疗产 ESBL 大肠埃希菌感染最有效的药物, 但耐碳青霉烯类抗生素的大肠埃希菌也均在各医院不断出现, 应当引起高度重视。

面对日益严重的细菌耐药性问题, 必须加强对目前使用的抗菌药物的管理, 尽可能延长抗菌药物的使用寿命, 减少细菌耐药性的出现, 同时应进一步做好细菌耐药性监测工作, 尤其是将来应开展针对特定感染部位病原菌的耐药性监测, 提高耐药性监测的水平和质量。

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收稿日期: 2015-04-02 修回日期: 2015-11-03